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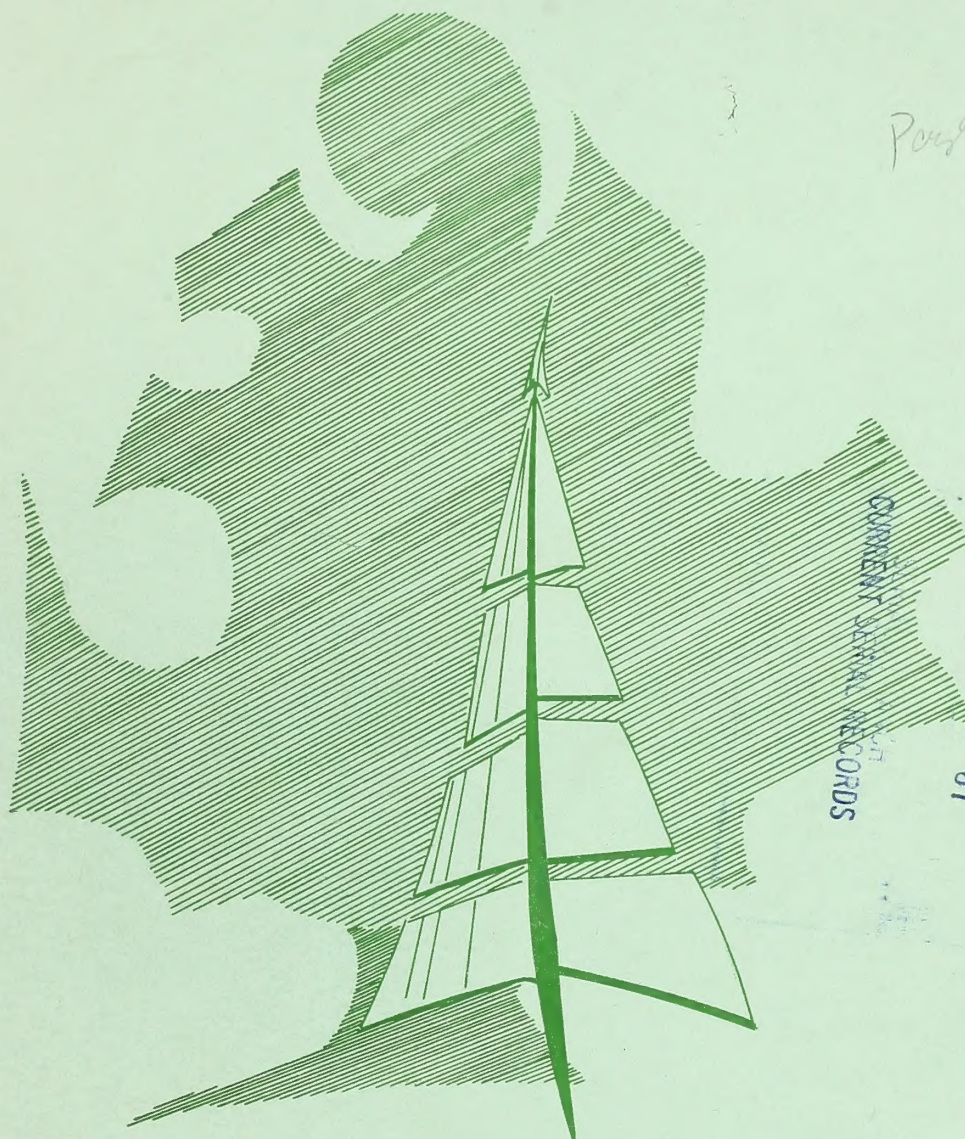
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PROCEEDINGS:

TWELFTH SOUTHERN FOREST TREE IMPROVEMENT CONFERENCE

JUNE 12 - 13, 1973

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PROCEEDINGS:

TWELFTH SOUTHERN FOREST TREE IMPROVEMENT CONFERENCE

BATON ROUGE, LOUISIANA

JUNE 12-13, 1973

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These proceedings contain papers given at the Twelfth Southern Forest Tree Improvement Conference. With 43 presentations and approximately 150 conferees, this conference provided an effective forum for sharing knowledge about our problems, both solved and unsolved. The whimsical verse by Barnett illustrates the scope of the conference. Review of the papers provides convincing evidence that genetics and breeding are viable, though not yet fully exploited, tools for the forest manager. We therefore dedicate these proceedings to the future and trust we have helped to keep a good thing growing.

At direction of the Southern Forest Tree Improvement Committee, conference chairmen undertook for the first time to assess publicly the nature and urgency of problems still facing us. Conclusions drawn from a survey of conferees are presented in these proceedings under Session VI. Full realization of the returns available from tree improvement depends upon careful consideration of these pressing needs by research managers.

Papers contained herein were printed as submitted by their authors. Conference chairmen made no attempt to edit, shorten or correct any of the material. Complete copies of these proceedings can be obtained from:

Director
Eastern Tree Seed Laboratory
Box 819
Macon, Georgia 31202

R. J. Dinus, B. A. Thielges
and O. O. Wells
Conference Chairmen

Observations on a SFTIC

'Twas during the wet spring of '73
Eons it now seems
I journeyed to Baton Rouge, La
To see what SFTIC means.

Thielges had made the arrangements
For a stay at the Prince Murat
Dinus and Wells had planned a program
Well calculated to knock off your hat.

Squillace and Weir, Rink and Rockwood
Barker, Snyder and Strickland as well
Talked about gains genetic in pines
And gave advanced generation breeding hell.

Seed orchard management next came on the scene
With problems and progresses too numerous to relate
But words like incompatibility, juvenility, stimulation,
Leptoglossus and radiography
Seemed to set the pace.

White, Hitt and McConnell
Next came to tell
How, why and where our tree germplasm we could conserve
And in some cases, sell.

At the end of this session, and justly so,
Everyone looked forward to the banquet to go
We ate crawdads and shrimp, frog legs and cat
Among other things 'till we knew we'd be fat.

After Thor had waxed eloquent and somewhat nostalgic
Concerning SFTIC--organization and mission
Justin Wilson made us laugh
'Till our sides were splittin'.

A partial night's rest
Provided strength to begin
With hardwood tree improvement--
Advances and gains.

We talked of oaks,
Red and others
Sweetgum, cottonwood
Sycamore and locust.

To end the main meeting with a bang, you see
There was a session called potpourri
With topics as diverse as you'd ever see
Hybrids, exotics, wood properties and phenoli.

What was the most important of all topics covered?
That will depend on where your interests lie
But the topic best remembered by attendees there
Was "Fill out that damned questionnaire."

P. E. Barnett
June 1973

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SESSION I

GENETIC GAINS AND ADVANCED GENERATION BREEDING

MODERATOR: B. J. ZOBEL

COMPARISON OF SOME ALTERNATIVE SECOND-GENERATION
BREEDING PLANS FOR SLASH PINE

A. E. Squillace^{1/}

Abstract.--In the breeding program at Olustee, Florida, a disconnected half-diallel mating scheme, with 6 parents per diallel, was chosen in preference to other mating schemes for establishing a second-generation base population. Genetic gains under this scheme are expected to be appreciably greater than schemes involving fewer crosses and will also provide reliable combining ability data for the original parents. In selecting offspring for clonal orchards, relatives will be permitted to a limited extent. Allowing the use of relatives to a moderate degree permits greater emphasis on family versus within family selection and the resulting gain exceeds losses expected from the mild inbreeding. Although a clonal orchard will give greater genetic gain than a seedling seed orchard, the gains will come sooner from the latter. Hence, conversion of a portion of the base population into a seedling seed orchard will also be considered.

Additional keywords: Breeding methods, inbreeding effects, Pinus elliotii

Many forest tree improvement workers are now making second-generation breeding plans. At Olustee, we have studied various approaches proposed by several authors (Libby, 1969 and 1972; Burdon and Shelbourne, 1971; and van Buijtenen, 1972) and made estimates of genetic gains for some of them. This paper gives the results of these analyses and outlines our tentative plans. Hopefully, the results and discussion will be helpful to others making plans for future breeding.

BACKGROUND

Several years ago, we launched a program designed to breed a "multi-purpose strains" of slash pine, to combine high oleoresin yield with other desirable traits (Squillace 1965). This effort should not be confused with the earlier work at Olustee, which successfully resulted in a high gum yield strain but in which emphasis was almost entirely on high gum yield. In the more recent program, we selected over 100 trees having the desired qualities, through cooperation of federal, state, and private forestry organizations. Most of these selections have been progeny tested under our short-term testing scheme, (Squillace and Gansel 1968) and scions from the best of the selections will be used in establishing clonal orchards.

Thus, in the "multi-purpose strain" program, we have completed one generation of breeding. Our next objective is to establish a new base population, which will form the basis for second-generation orchards and further breeding. We plan to use approximately 100 selections in establishing the

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base population rather than only the clones being selected for first-generation seed orchards, in order to provide a broad base. The desirability of keeping base populations separate from seed orchards has been pointed out by Franklin (1973). The major question now is, "What breeding scheme should we use in developing the new base population?"

Without very much contemplation, we decided to use individual tree matings rather than polymix matings. The main reason for this choice is that by making individual tree crosses and keeping family identity, we will have control on future inbreeding.

The selection of a mating design for the 100 P_1 selections required more study. A minimum effort would be to breed each tree once. This "single-pair" mating scheme, proposed by Libby (1972), would require only 50 full-sib families, all of which would be unrelated. Alternatively, we could produce more matings on each tree. One practical method is the disconnected half-diallel (d.h.d.). Under this method, the parent trees are divided into a number of groups and then trees are crossed within each group in a half-diallel manner, excluding selfs and reciprocals. For example, we could divide the parent into 20 groups of 5 each, and there would then be a total of

$$\frac{Np(p-1)}{2} = 200 \text{ full-sib families (N = number of groups and p = number of parents per group)}$$
We shall call this a "5-parent d.h.d.". Note that a "single-pair" mating scheme can be called a "2-parent d.h.d.". Note also that for d.h.d.'s containing more than 2 parents per group, there will be half-sib relationships as well as full-sib relationships in the progeny. For convenience, all the progeny of one parent will be called a "half-sib family" although it actually consists of two or more full-sib families.

Disconnected half-diallels with say 5 or 6 parents per group would, of course, have the advantage of providing reliable combining abilities for each parent. In our case, this would be of some importance as it provides a basis for roguing of first-generation orchards. The major question is, however, would producing relatively large numbers of families provide greater genetic gains in second-generation orchards?

In order to get an answer to this question, a theoretical analysis of genetic gains possible for d.h.d.'s of varying group sizes was made. At the same time, it was considered desirable to determine the optimum selection scheme for development of second-generation clonal orchards. Finally, some attention was given to the desirability of converting a portion of the base population into a seedling seed orchard.

ESTIMATION OF GENETIC GAINS FROM DISCONNECTED HALF-DIALLEL SCHEMES

In computing the expected gains, the base population was held constant at 7500 trees. Thus, in a 2-parent d.h.d., we would produce and plant 150 offspring from each of 50 full-sib families. In a 3-parent d.h.d., we would plant 75 offspring from each of 100 full-sib families, etc.

It was further assumed that, under each scheme, 25 offspring would be selected for use in clonal orchards. Thus, the proportion of offspring to be selected in each case would be $25/7500 = 1/300$. Narrow-sense heritability on an individual tree basis was assumed to be .25, a reasonable value for growth rate. However, computations for heritabilities of .50 and .75 were also made, mainly to reveal trends for changing heritability.

The selection schemes were designated 1 through 5, which are the number of offspring selected per full-sib family. In each case, the number of half-sib or full-sib families had to varied accordingly, so that the number of trees selected in each case totaled 25. For example, in the 2-parent d.h.d. under scheme 1, we select the best tree in each of the best 25 full-sib families; in scheme 2, we select the best 2 trees in each of the best 12-1/2 families, etc.; finally, in scheme 5, we select the best 5 offspring in each of the best 5 families.

For d.h.d.'s involving more than 2 parents, we had the alternative of varying the numbers of half-sib families to be selected as well as full-sib families within them. But preliminary analyses suggested that gains would be greatest by placing the greatest intensity of selection on full-sib families. Hence, the number of half-sib families and individuals to be selected were varied and the number of full-sib families were held constant at 1 per half-sib family.

Since in some cases, we would be choosing relatives, allowances were made for inbreeding. On the basis of Gansel's (1971) report, it was estimated that inbreeding losses, due to using relatives in seed orchards, might be approximately .4 standard deviations per .1 of F (the inbreeding coefficient). For stem volume, this is roughly equivalent to a loss of about 12 percent of the mean per .1 of F.

Computations of gross genetic gains were made using separate formulae for family and for within-family selection given by Falconer (1960, p. 235). Admittedly, combined selection (which gives proper weights to the individual's value and its family mean) would result in greater gains. But if combined selection was used, we could not properly deduct for inbreeding losses, since we would not know the numbers of relatives that would be chosen. Details of computations are exemplified in Appendix Table 1 and results are presented in Figure 1. Estimated gains are given in terms of phenotypic standard deviations (σ_p) of individuals, and this was assumed to be constant over all base populations. (As near as could be determined with a hypothetical model, increasing the number of families does not change the overall phenotypic standard deviation. An opportunity to check on this with actual data from diallel mating schemes was also available and no appreciable change could be found in σ_p , in going from 2-parent to 4-parent d.h.d.'s). If one knows the standard deviation and mean (and hence, the coefficient of variation) for a particular situation, the gains can be converted into a more understandable measure. For example, if the coefficient of variation in volume growth is 30 percent, a gain of .8 σ_p would be equivalent to about 24 percent of the mean.

Note that estimated gains increase in going from a 2-parent d.h.d. to a 6-parent d.h.d., rapidly at first and then more slowly (figure 1). For example, if one selects a single offspring per full-sib family, the expected gain is about $.63 \sigma_p$ for a 2-parent d.h.d. and about $.85 \sigma_p$ for a 6-parent d.h.d., which converts roughly to 19 versus 25 percent of the mean, assuming a coefficient of variation of 30 percent. Genetic gains for an 8-parent d.h.d., not shown in Figure 1, would be only slightly higher than those for the 6-parent d.h.d.

Apparently, the differences between mating schemes are due to differences in the allocation of the overall proportion of trees selected (1/300) to family and within-family selection and to the fact that, for low heritability, family selection is much more effective than within-family selection. For example, under a 2-parent d.h.d. with 1 selection per full-sib family, we select the best 25 of 50 families and the best 1 of 150 individuals within families. In a 5-parent scheme, on the other hand, we select relatively more intensively for families (1/8 for families and 1/37.5 for individuals within families).

Note also in Figure 1 that gains increase in going from selecting 1 offspring per full-sib family to 2 or 3 offspring per full-sib family and then decrease thereafter. Gross gains actually increase continuously in going from 1 to 5 trees selected per family. This is due, again, to increasing intensity of family versus within-family selection. The net gains, however, show a curvilinear effect, with an optimum, because of increasing inbreeding losses. Thus, selecting relatives up to a certain point (2 or 3 trees per full-sib family) results in greater net genetic gains than entire avoidance of relatives.

With high heritabilities, (.50 and .75) the results were similar to those for a heritability of .25, but the relative advantage of producing more families and of selecting more than one offspring per family decreases as heritability increases.

Under actual conditions, it may be preferable to make selections using a combined (family + within-family) index (Falconer, 1960, p. 236). If this procedure is used without restriction relatives will likely be chosen. In order to check further on the effect of selecting relatives, two kinds of selection were compared using data from 3 progeny tests at Olustee: 1) unrestricted combined selection and 2) combined selection restricted to avoid relatives. As expected, unrestricted combined selection resulted in highly varying numbers of selections per family (table 1). But the inbreeding coefficient in each case was rather small and the estimated losses were likewise small. The net genetic gains from unrestricted combined selection exceeded the gain from restricted combined selection in all three tests. In test G-62, unrestricted combined selection resulted in 9 selections from one family. In practice, one should avoid that many selections from one family, holding it to a maximum of say 5. This may reduce gains slightly, but it would perhaps be safer--a highly superior family may fail at a later date.

Figure 1.--Expected net genetic gains (after allowance for inbreeding losses) from establishing base populations by disconnected half-diallel (d.h.d.) mating schemes and selecting trees by several methods for use in clonal orchards.

Conditions:

Breed 100 P_1 selections by one of five schemes
 Plant 7500 offspring
 Select 25 offspring for clonal orchard by one of five schemes (horizontal axis--see text)
 $h^2 = .25$

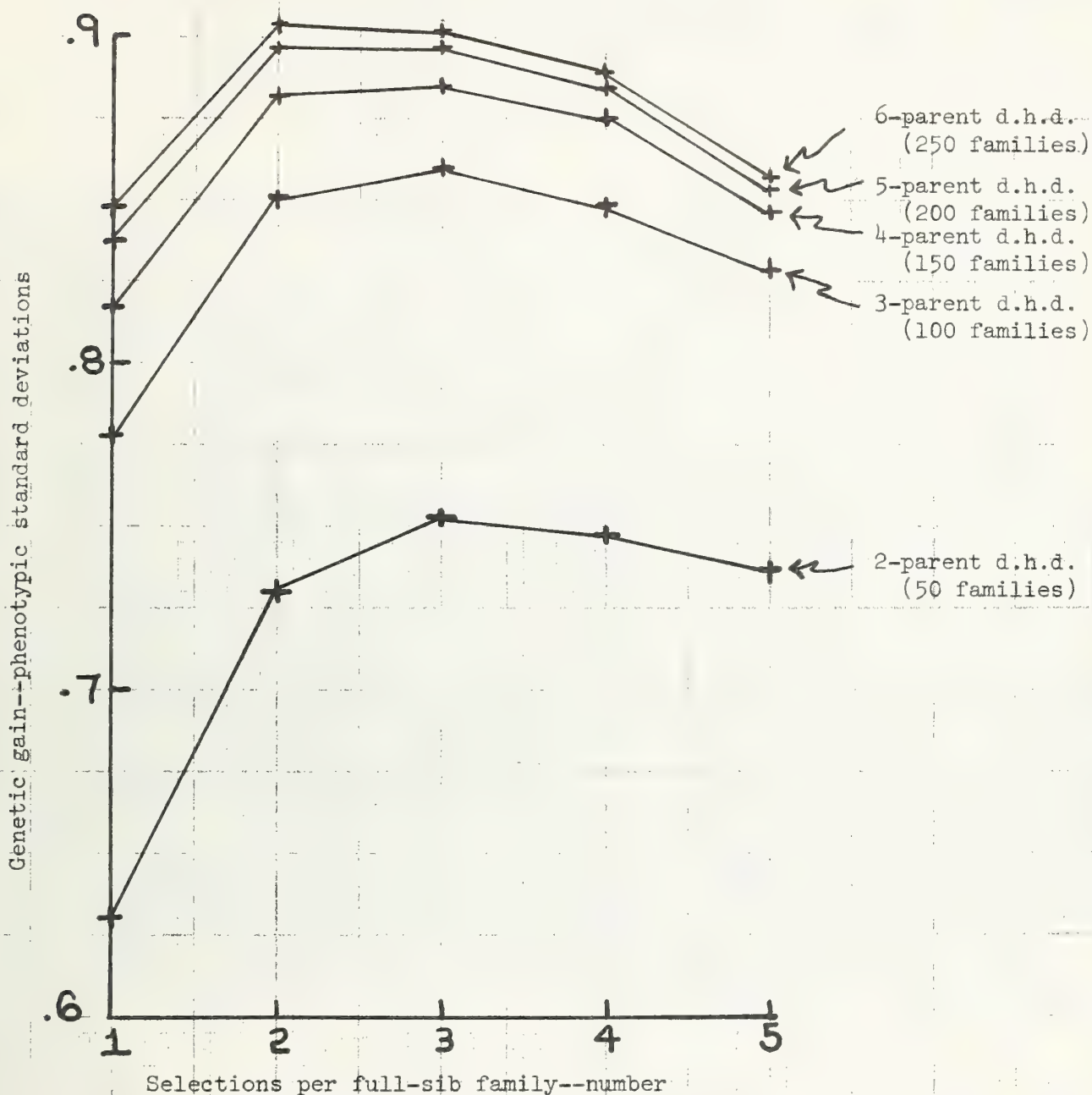


Table 1.--Estimated genetic gains in height growth from unrestricted combined selection versus combined selection restricted to avoid relatives, in three slash pine progeny tests.

	Test G-48A	Test G-62	Test G-49
TEST DATA			
Age of trees years	10	3	10
Total families number	31	30	50
Total trees number	930	600	500
Average index value	129.7	30.0	73.3
UNRESTRICTED COMBINED SELECTION			
Average index value for 25 selected trees	141.7 ^{1/}	34.2 ^{2/}	84.0 ^{3/}
Gross genetic gain percent	9.2	14.0	14.6
Estimated inbreeding coefficient for progeny of selected trees ^{4/}008	.025	.011
Estimated loss from inbreeding . . percent	- .4	-1.5	-0.7
Net genetic gain percent	8.8	12.5	13.9
COMBINED SELECTION RESTRICTED TO AVOID RELATIVES			
Average index value for 25 selected trees	139.3	32.5	82.0
Genetic gain percent	7.4	8.3	12.0

^{1/}Selections occurred in 14 families. The number of selections in them were 5, 3, 3, 2, 2, 2, 1, 1, 1, 1, 1, 1, 1, and 1, respectively.

^{2/}Selections occurred in 8 families. The number of selections in them were 9, 6, 5, 1, 1, 1, 1, and 1, respectively.

^{3/}Selections occurred in 10 families. The number of selections in them were 6, 5, 3, 2, 2, 2, 2, 1, 1, and 1, respectively.

^{4/}Excluding selfing and assuming random mating among trees.

SEEDLING SEED ORCHARDS

Although we tentatively plan to use the clonal orchard approach, a cursory analysis was made to see what gains could be obtained by a seedling seed orchard approach. Here it was assumed that 1) the base population would be established from a 5-tree d.h.d.; 2) a 10-acre portion of it would be converted into a seedling seed orchard; and 3) that the trees for it would be planted at random in individual tree plots, at a spacing of 30 sq. ft. per tree. Thus, there would be about 1450 trees per acre. We would make a light early thinning (say at 5 years) and then a final one at 10 years, leaving 50 trees per acre. Thus, the proportion of trees selected is $50/1450 = .034$. The selection intensity here is considerably less than that used in the clonal orchard approach and hence, the genetic gains cannot possibly be as great as in the latter. Allowance was made for the relative inefficiency of the early thinning. Heritability was again assumed to be .25.

The estimated gain from the seedling seed orchard approach could not be accurate because it was not possible to determine the numbers of relatives that would occur and hence, the inbreeding losses allowed were little more than guesses. But the genetic gain turned out to be $.60 \sigma_p$, which is appreciably less than expected gains from the clonal orchard in the 5-parent d.h.d., as expected.

However, there are other points to consider. When the base population is 10 years old, and is converted into a seedling seed orchard, it would perhaps start producing appreciable amounts of seed in a couple of years. On the other hand, if instead, we begin a clonal orchard at this time, a lapse of about 10 years would occur before seed production. Thus, genetic gains from the seedling seed orchard would come sooner than those from a clonal orchard. Also, the cost of establishing the former may be less. An economic analysis would be required to make a good comparison. At Olustee, we are considering converting a portion of the base population into a seedling seed orchard, on an experimental basis.

SUMMARY AND CONCLUSIONS

In our tree breeding program at Olustee, we are planning to establish a new base population from 100 genetically superior P_1 selections to be used for further selection and breeding. Analyses, based largely on theory, were conducted to help decide on a breeding approach and on schemes for developing second-generation orchards. Expected genetic gains were computed for disconnected half-diallel mating schemes, with from 2 to 8 parents per diallel, and for 5 selection schemes.

Estimated genetic gains increased appreciably with increasing number of parents per diallel up to about 4. We have tentatively decided to use a 6-parent scheme. But we expect to end up with the approximate equivalent of a 5-parent scheme because some matings will likely be difficult to make and we do not consider it necessary to make all of them. A 5- or 6-parent disconnected diallel will also provide reliable data on the combining ability of each parent. The analyses also suggested that in choosing offspring for a clonal orchard, the breeder will achieve appreciably greater genetic gains if he includes relatives to a modest degree (such as about 2 to 3 full-sibs per selected family) than if relatives are avoided entirely. This was true for conditions specified in the study, ($h^2 = .25$ and 25 clones per orchard) and would likely be true generally when heritability is low and when at least 25 clones per orchard are used. We have decided to use combined (family + within-family) selection, restricted to the extent of permitting not more than about 5 full-sibs per family.

Conversion of the base population into a seedling seed orchard was also considered as an alternative to establishing clonal orchards. Genetic gains are expected to be somewhat less than the clonal orchard approach. But improved seed will be obtained sooner and the costs may be less for the seedling seed orchard. This approach should be examined further.

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Appendix Table 1.--Estimated net genetic gains for a 5-parent disconnected half-diallel under 5 selection schemes.1/

Selection scheme			Inbreeding			Half-sib selection			Full-sib selection			Within full-sib family selection			Net gain
h	f	w	\bar{r}_o	\bar{F}	Loss	P_h	I_h	R_h	P_f	I_f	R_f	P_w	I_w	R_w	
No.	No.	No.	σ_p			σ_p			σ_p			σ_p			σ_p
25.00	1	1	.00	.00	.00	.50	.80	.22	.25	1.27	.34	.03	2.13	.28	.84
12.50	1	2	.02	.01	-.04	.25	1.27	.34	.25	1.27	.34	.05	1.93	.25	.89
8.33	1	3	.04	.02	-.08	.17	1.50	.40	.25	1.27	.34	.08	1.78	.24	.90
6.25	1	4	.06	.03	-.12	.12	1.65	.44	.25	1.27	.34	.11	1.66	.22	.88
5.00	1	5	.08	.04	-.17	.10	1.76	.47	.25	1.27	.34	.13	1.56	.21	.85

1/ Conditions

100 P₁ selections, divided into 20 groups of 5 each.

Selections mated to produce 200 full-sib families, each containing an average of 37-1/2 offspring.
Plant 7500 offspring (base population).

Select 25 offspring for use in developing a second-generation clonal orchard.

Computations for selection scheme 2 (second row of table).

$$1) \text{ Inbreeding loss} = 4 \bar{F} \sigma_p = 4 (.01) \sigma_p = .04 \sigma_p$$

\bar{F} = average inbreeding coefficient of second-generation orchard, excluding selfing and assuming random mating among clones

$$\bar{r}_o = \frac{.02}{2} = .01$$

\bar{r}_o = average coefficient of relationship among offspring selected

$$= \frac{w(f+1) - 2}{4(hfw - 1)} = \frac{2(1+1) - 2}{4[(12.5)(1)(2)]} = .02$$

h = number of half-sib families selected = 12.5

f = number of full-sib families selected within half-sib families = 1

w = number of individuals selected per full-sib family = 2

2) R_h = genetic gain from half-sib selection

$$= I_h \sigma_h^2 \cdot \frac{1 + (n_h - 1)r_{eh}}{\sqrt{n_h \{1 + (n_h - 1)t_h\}}}, \quad (\text{Falconer, 1960, p. 235})$$

$$= 1.27 \sigma_p (.25) \cdot \frac{1 + (150 - 1)(.306)}{\sqrt{150\{1 + (150 - 1)(.077)\}}} = .34 \sigma_p$$

I_h = 1.27 = selection differential in standard measure, corresponding to P_h .

P_h = proportion of half-sib families selected = .25 (Note. There will be 100 half-sib families, each containing 4 full-sib families, utilizing each full-sib family twice. Hence, although an average of only 12.5 half-sib families will be selected, P_h is considered to be 25/100 rather than 12.5/100 in order to avoid selection of the same full-sib family twice. This makes the overall proportion selected 1/300, as required (25/100 for half-sib selection, 1/4 for full-sib selection, and 2/37.5 for individual selection)).

σ_p = phenotypic standard deviation of individuals.

h^2 = heritability of individuals = .25

n_h = number of individuals per half-sib family = 150.

r_{eh} = effective coefficient of relationship between members of half-sib families (Lush, 1945, p. 325).

$$= \frac{\bar{r}_{wh} - \bar{r}_{bh}}{1 - \bar{r}_{bh}} = \frac{.3122 - .0082}{1 - .0082} = .306$$

\bar{r}_{wh} = average coefficient of relationship within half-sib families.

$$= \frac{n_h(f_h + 1) - 2}{4(f_h n_h - 1)} = \frac{150(4 + 1) - 2}{4[(4)(150) - 1]} = .3122$$

f_h = number of full-sib families per half-sib family = 4

\bar{r}_{bh} = average coefficient of relationship between half-sib families

$$= \frac{3p - 2}{4(N - 1)(p - 1)} = \frac{3(5) - 2}{4(100 - 1)(5 - 1)} = .0082$$

N = total number of parents = 100

p = number of parents per half-diallel group = 5

t_h = phenotypic correlation between trees in half-sib families

$$= h^2 r_{eh} = .25(.306) = .077$$

3) R_f = genetic gain from full-sib selection

$$= I_f \sigma_p h^2 \cdot \frac{1 + (n_f - 1)r_{ef}}{\sqrt{n_f\{1 + (n_f - 1)t_f\}}}, \quad (\text{Falconer, 1960, p. 235})$$

$$= 1.27 \sigma_p (.25) \cdot \frac{1 + (37.5 - 1)(.333)}{\sqrt{37.5\{1 + (37.5 - 1)(.083)\}}} = .34 \sigma_p$$

I_f = 1.27 = selection differential in standard measure corresponding to P_f

P_f = proportion of full-sib families selected = .25

n_f = number of individuals per full-sib family = 37.5

r_{ef} = effective coefficient of relationship between members of full-sib families

$$= \frac{r_{wf} - r_{bf}}{1 - r_{bf}} = \frac{.50 - .25}{1 - .25} = .333$$

r_{wf} = coefficient of relationship within full-sib families = .50

r_{bf} = coefficient of relationship between half-sib families = .25

t_f = phenotypic correlation between trees in full-sib families

$$= h^2 r_{ef} = .25(.333) = .083$$

4) R_w = genetic gain from selection of individuals in full-sib families

$$= I_w \sigma_p h^2 \cdot (1 - r_{wf}) \sqrt{\frac{n_f - 1}{n_f(1 - t_w)}}, \quad (\text{Falconer, 1960, p. 235})$$

$$= 1.93\sigma_p(1.25)(1 - .50) \sqrt{\frac{37.5 - 1}{37.5(1 - .125)}} = 25\sigma_p$$

I_w = 1.93 = selection differential in standard measure, corresponding to P_w

P_w = proportion of individuals selected within full-sib families = .05

t_w = phenotypic correlation between trees in full-sib families = $h^2 r_{wf}$ = $.25(.50)$ = .125

Net gain = Inbreeding loss + R_h + R_f + R_w = $(-.04 + .34 + .34 + .25)\sigma_p = .89\sigma_p$.

REALIZING GENETIC GAINS THROUGH
SECOND-GENERATION SEED ORCHARDS

Robert J. Weir^{1/}

Abstract.--Second-generation forest tree seed orchards are being established with early selections from first-generation progeny tests. Although much has been learned from first-generation orchard experience, there are new challenges encountered and new methods used to achieve maximum effectiveness in this second improvement cycle.

Effective procedures for selecting trees with outstanding general combining ability, the best trees of the best families, are being developed. Precautions are necessary to avoid detrimental inbreeding effects by using only individuals with known pedigrees in the new orchards.

Second-generation orchards are established at close spacing to allow for further selection through roguing following more complete testing. In addition, several outstanding first-generation clones are grafted to provide an early pollen source for second-generation grafts.

Based upon our knowledge of heritability and selection differentials, genetic gains of 20% in growth over and above first-generation orchards can be predicted. Although major emphasis has been placed on growth rate and disease resistance, a threshold value for form and quality traits will be maintained.

Additional keywords: Selection methods, orchard establishment, inbreeding depression.

INTRODUCTION

In an applied forest tree improvement program, even small genetic gains can bring enormous returns when distributed over thousands of acres annually. For this reason it is imperative that the improved material resulting from recurrent selection efforts be introduced into the production phase at the first practical point in time. Such activities are underway with the N. C. State University-Industry Cooperative Tree Improvement Program^{2/} which has begun establishment of second-generation production seed orchards. Through the spring of 1973, eight cooperators have started establishment of 10 orchards. Currently totaling 40 acres, these orchards will consist of over 400 acres of commercial forest tree seed orchards when completed.

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^{2/}The Cooperative membership is composed of 25 industrial and three State Forest Service members in 13 southeastern states having combined regeneration programs of over 300 million trees annually.

While many of the techniques are similar and there is much to be gained from the first-generation orchard experience, new and improved technology is being utilized with the second applied improvement cycle. This paper describes the second-generation orchard program being implemented by members of the N. C. State University Cooperative. Where appropriate, suitable alternatives which may find application under a differing set of conditions are examined.

Selection Base

Over 1400 acres of control-pollinated progeny test plantings have been established in conjunction with the N. C. State University-Industry Cooperative Tree Improvement Program. These tests, which include over 6000 control cross seed lots, have the dual objectives of (1) assessing breeding values of seed orchard parents, and (2) providing a base population from which individuals are selected to serve as parents in second-generation production seed orchards.

Use of control cross progeny with complete pedigrees is mandatory if the potentially damaging effects of inbreeding are to be avoided. Nearly every orchard in the Cooperative progeny test program has been shown to contain several clones (5 to 20 percent of the clones tested) which are excellent general combiners (Weir and Zobel, 1972; Zobel, et al., 1972). If mass selection is practiced, i. e., selecting the best individuals with no regard to family performance, progeny from the outstanding clones are chosen at much higher frequencies than would be expected from the frequency with which the clones occurred in test plantings. This is evidenced by the second-generation selections from loblolly pine under test by International Paper Company, Georgetown, S. C. (Figure 1). If selections were made from tests identifying only one parent (open-pollinated, top-cross or pollen-mix matings where only the mother is identifiable) the chances are very high that many selections would have one common male parent. Use of such selections in production seed orchards could result in disastrous genetic gain reduction resulting from inbreeding depression. Volume growth depression of 20 percent has resulted from matings among half-sibs (Gansel, 1971). Discretion then dictates that related matings be avoided and this can only be assured when the complete pedigree of second-generation seed orchard parents is known.

It is of additional concern that the population serving as a base for selection of second-generation orchard parents be derived from a mating scheme which provides a sufficient number of unrelated families so as to allow inbreeding avoidance. Nearly all the Cooperative progeny tests have employed a tester design wherein four to six clones designated as testers are mated to all other clones. For any single breeding program this is a severe restriction on the number of unrelated families created; there can be no more unrelated crosses than the four to six testers used in the breeding program, no matter how many clones are under test. The tester system does have application in a cooperative where member organizations within a region pool their resources to obtain the 20 to 40 unrelated selections required to establish a second-generation production seed orchard. However, breeding programs which must stand alone and have a single closed system would find the tester design

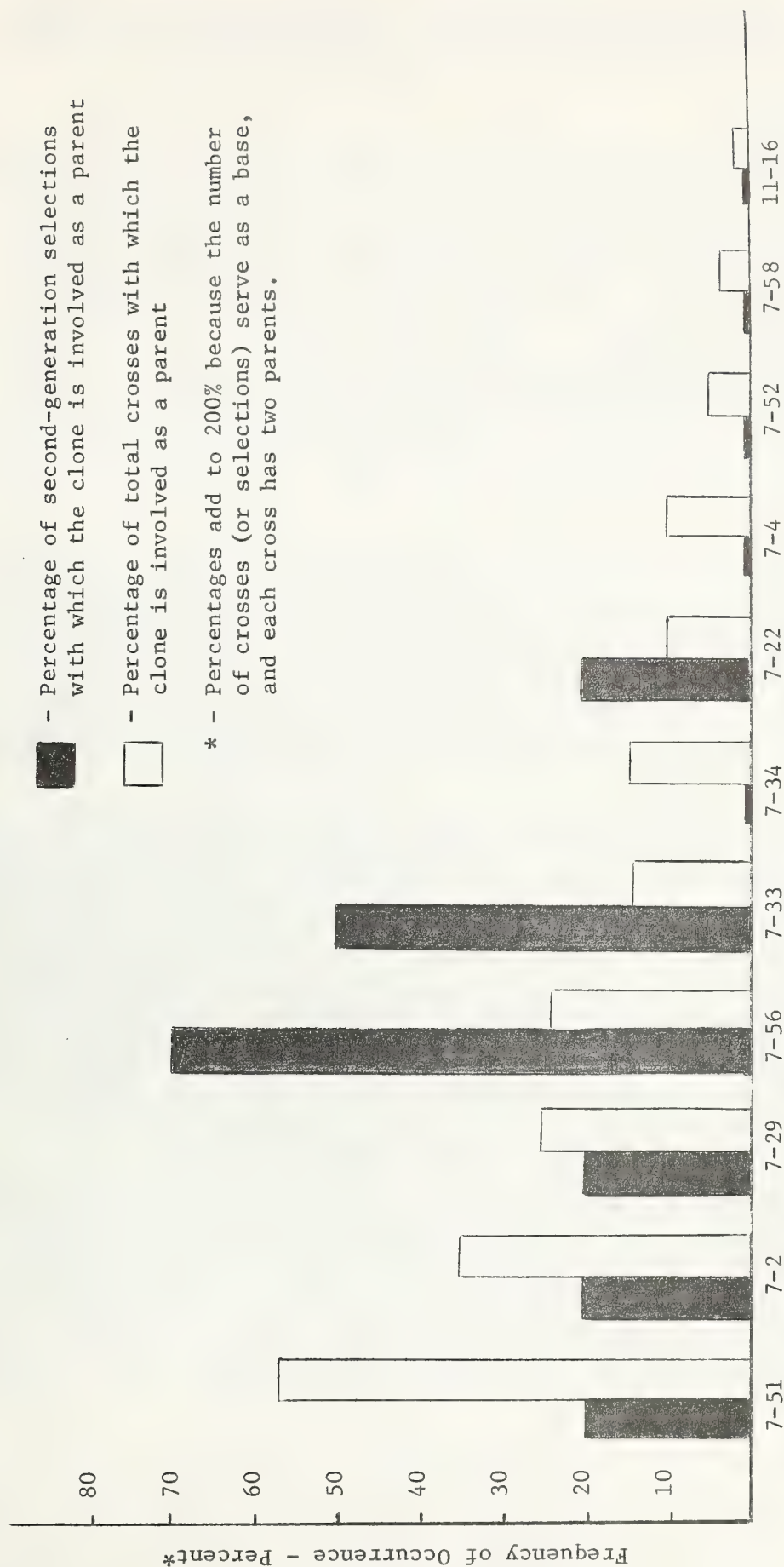


Figure 1. Comparison of the percentage of second-generation selections with which a clone is a parent, related to the percentage of all crosses using that clone as a parent

inadequate. They should resort to one of several alternative breeding schemes described which would properly serve their needs, e. g., Zobel, et al., 1972; van Buijtenen, 1972; Franklin, E. C. and Squillace, A., 1973.

Selection Methods

Before any advanced-generation selection is done, one must determine when to select with respect to progeny age. Early selection will allow a more rapid turnover of generations but would tend to result in more selection errors as a result of lower juvenile-mature correlations (LaFarge, 1972; Sluder, 1972; and Wakely, 1971). However, delaying second-generation parent selection until selection errors are eliminated would also delay the commercial utilization of available improved material. Compromises are needed to optimize the total cumulative improvement as measured over time. Published accounts of such efforts have recommended selection at surprisingly early ages (Nanson, 1970; Squillace, 1972). It is apparent that the greatest long-term improvement is achieved by effecting a rapid turnover of generations rather than waiting to assure that the transition from one generation to the next is made, with only proven winner selections.

The Cooperative's initial second-generation selection work provided for early establishment of records on outstanding trees in each progeny test. Initial selections were identified by a two-stage process which included screening four-year field measurement data in the office and field assessment during or after the fifth growing seasons. At this time three or four ramets of each selected tree were grafted into a research clone bank to allow evaluation of graftability and eventually flower production and phenology. The tentative selections continue to develop in the progeny tests and are scheduled for reassessment at age 9 and again at approximately age 12.

Many trees having the desired combination of growth, form, and disease resistance characteristics were identified in the above manner. The procedure is best described as mass selection whereby outstanding trees were chosen solely on their own phenotypic superiority. Such a selection system is analogous to wild stand selection used with the initial improvement cycle except that it has been more effective as a result of greater environmental control including uniform sites, spacing, competition and identical aged trees. However, the theoretical limitations to this approach were realized as evidenced by the too frequent selection of outstanding individual trees which came from below average parents, i. e., too many good trees from poor families were picked. Although some of these trees have been retained for testing, it is recognized that selection of such trees will theoretically not yield as much genetic gain as combined family and within-family selection.

As second-generation selection work progressed and the need to establish production orchards with the most improved material available became evident, selection techniques were refined to include both family and within-family performance. An independent culling level system was introduced which included:

1. Selection of individuals from only those full-sib families which rank in the top 50% for a given test in growth traits.

2. The individual tree height is arbitrarily required to exceed the sum of the test average plus twice the square root of error variance (replication by family interaction).
3. The tree must be disease-free.
4. The tree must score above average in both crown conformation and stem straightness ratings.
5. Culling levels have been introduced at the 8-year assessment to reflect selection for wood specific gravity and volume. Requirements for volume superiority are determined as for height.

The independent culling level approach is applied in two stages. First the measurement data are screened and then an on-site assessment of each candidate tree is made prior to final acceptance. The independent culling level system has led to marked improvement in selection; most trees chosen are derived from progenies of the very best general combiners from the initial seed orchard. However, such an approach has shortcomings and continual improvements are being developed.

When only full-sib family performance is used as a basis for family selection, a bias is introduced. Intended selection for high general combining ability may in fact reflect outstanding positive dominance deviations or specific combining ability which is of little utility using current production seed orchard methodology. Future evaluation work is to be revised to include half-sib family selection (general combining ability) as well as full-sib family selection. Simultaneously methods are being devised to make use of sibling information from other tests in other years and locations.

The ultimate refinement in second-generation selection would be development of indices which optimize the weighting of half-sib, full-sib and individual tree values. However, if index selection is to be applied, accurate variance estimates or heritability estimates are needed to determine the appropriate weights. Good estimates are not usually obtainable from most progeny tests, since such tests are not designed for variance estimation but rather to evaluate first-generation clonal performance. An alternative is to use published heritability estimates or variance component estimates but this introduces the inherent dangers of extrapolation from data which apply to only one population in one single location or set of locations. Results using index selection can be no better than the data used to construct the index.

The full- and half-sib family information base will increase simultaneously with development of improved selection methods. The results of these advances are already apparent and indicate that, increasingly, selected trees come from matings among only the very best and strongest general combiners of the first-generation breeding population. While breeders strive arduously for such gratifying results which are prerequisite to maximizing genetic improvement, a subsequent dilemma results in the applied or production phase of the program. One is constantly confronted with the decision of whether

it is best to use several outstanding but related selections or to use moderately good clones with no common ancestors. Certainly some related selections can be used with restrictions (see next section) but the extent of such use will depend on the magnitude of inbreeding depression resulting from related matings.

ORCHARD ESTABLISHMENT

Although the pressure to establish second-generation orchards has been intense by those who rightfully want to maximize production by using the available improved genetic material, it is necessary to move slowly and not rush immediately into large acreages of second-generation orchards. We have chosen to move deliberately, with each Cooperative member currently establishing only two to four acres of second-generation seed orchards in any one year. This allows an annual reassessment of the second-generation selections and provides for establishment each year of the best available clones, including any new selections which may have been obtained since the previous grafting season.

Initially we are establishing second-generation clonal seed orchards at 15' x 15' spacing, modified by leaving every second position in every second row open. Approximately 145 grafted trees per acre are established. The alternate rows having alternate blank spaces are staggered such that each tree is surrounded by no more than three immediately adjacent neighbors (Fig. 2).

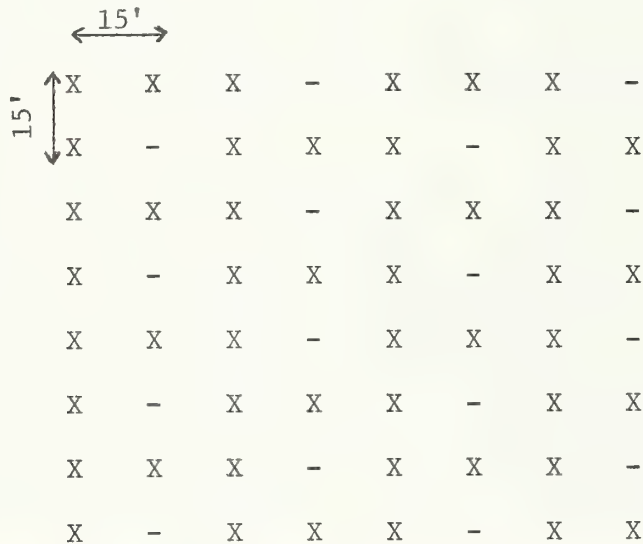


Figure 2. Second-generation orchard layout
 X = Grafted Tree
 - = Vacant Position

Staggering the alternate, half-filled rows will delay the first orchard thinning one or several years, with no adverse effect on total seed production due to overcrowding.

More trees are established per acre than will be left after roguing, so as to allow for flexibility to remove the poorest individuals. Since the majority of the selections are currently being assessed and grafted after only five growing seasons in the field, some poor individuals will be chosen. We have found that some selections do not maintain the required superiority as time progresses. If we are to begin orchard establishment as early as the fifth year, it is imperative that the system be flexible enough to allow roguing of trees that do not develop as expected. In subsequent years, when the majority of the clones being established are at least eight to ten years old, the number of clones and grafts per acre will be reduced accordingly.

For flexibility in roguing it is necessary to establish as many trees per acre as feasible and to graft many different clones into each orchard. This is being done as a result of the stepwise establishment procedure with new selections being added each year. In contrast, however, there is need to use only the best clones so as to maintain a selection intensity sufficient to achieve substantial genetic gains prior to roguing. This constant dilemma must always be faced and the direction chosen for the inevitable compromise will depend largely on the strength of the juvenile-mature correlation among actual and potential second-generation selections. There is, however, a lower limit to the number of clones which must be included in the second-generation orchard if one is to achieve the desired 90- to 100-foot spacing between ramets of the same clone and thus minimize chances for selfing (McElwee, 1970). With the recommended layout described above (Fig. 2), a minimum of 18 unrelated clones are needed to maintain compliance with the 90- to 100-foot rule. If it is necessary to use related (half-sib) selections when developing the clonal arrangement, they must be separated by 90 to 100 feet just as if they were ramets of the same clone. Thus a pair of related clones effectively counts as only one clone in the determination of the total number of clones needed or being used.

Previous experience with grafts of young trees has indicated "female flower" production will commence in a 3- to 5-year period after grafting. Usually pollen production lags several years behind this (personal communication, Bruce Zobel^{3/}). In an effort to provide an interim pollen source, we use several of the very best general combiners from first-generation orchards, grafted into the second-generation orchard as "pollen parents." This is sometimes difficult, however, since the most outstanding first-generation parents are nearly always related to the best second-generation selections. Thus, again, a compromise must be reached as to which pollen parents are to be employed if inbreeding is to be avoided. The most common result is that we use the best available unrelated first-generation clones. Such trees provide a satisfactory interim pollen source, but since they will be rogued as soon as the second-generation clones produce pollen they will provide no long-term dilution of genetic gain in the advanced-generation orchard.

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In first-generation seed orchards, a 400- to 500-foot isolation or dilution zone is maintained which is kept clean of any trees that will pollinate the orchard species. Such a zone appears to be an effective means of increasing the ratio of improved to contaminating pollen (McElwee, 1970). Such dilution zones are more critical for second-generation orchards, as the contaminating pollen from wild stands becomes, in relative terms, increasingly inferior to that from the orchard trees. Although of less importance, second-generation orchards should also be isolated from first-generation orchards. If this cannot be fully accomplished, the adjacent portions of the first-generation orchards must be very severely rogued prior to the onset of commercial flower production in the new advanced-generation orchard.

Genetic Gains

The ultimate objective of the Cooperative is to produce enough seed to meet all regeneration requirements for each cooperator. Simultaneously, we strive to maximize the genetic quality of such seed at any given point in time. We look forward to the assessment of realized genetic gains to be obtained through second-generation production seed orchards, but until this is possible we must estimate the benefits of improvement efforts by means of predicted genetic gains.

Results to date show realized gain in growth resulting from first-generation seed orchards ranges from 10 to 20 percent. Although more difficult to quantify, gains in quality traits such as crown conformation and bole straightness have been even more dramatic. Because of the occurrence of escapes and the nature of inheritance, mass selection for rust resistance has resulted in only minimal improvement. However, when combined with progeny testing and subsequent roguing or establishment of improved-first-generation orchards, the percentage of rust infected trees can be reduced by as much as 20 percent (Blair and Zobel, 1971).

The outlook for genetic gains possible from second-generation seed orchards is bright. Based upon the most reliable estimates of heritability available in conjunction with realistic selection differentials, a genetic gain of 25% has been predicted for volume growth, obtained as a consequence of mass selection (Stonecypher, et al., 1973). With family plus within-family selection volume improvement could be even greater. Such improvement is expected over and above that which was achieved in the first generation. Although family plus individual within-family selection for percentage of trees rust free is impossible, family plus within-family selection for number of galls per tree has shown gains from 50 to 90 percent to be possible (Blair and Zobel, 1971). Additional improvement in form characteristics can be achieved, but because of the excellent response to previous selection, merely maintaining the level of improvement realized to date will be satisfactory. The philosophy behind such strategy recognizes that additional improvement in form traits would be obtained at the expense of additional gains in growth or disease resistance. The value for additional upgrading of form would not offset the value of volume or growth improvement which would be sacrificed.

It must be recognized that the predicted gains previously suggested do not reflect the consequences of multiple-trait selection. While major emphasis is being placed on growth, adaptability and disease resistance, and gains in each will be high, they may not equal the single-trait predictions of above when sought simultaneously. It is very apparent, however, that the genetic gains to be obtained from a properly executed second-generation seed orchard program are well in excess of improvements realized to date. Second and subsequent improvement cycles are expected to have an increasingly greater impact on intensive forest management efforts throughout the South.

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INHERITANCE AND GAINS OF THREE WOOD PROPERTIES IN VIRGINIA PINE

George Rink and Eyvind Thor^{1/}

Abstract.--Wood cores were obtained from a six-year-old open-pollinated Virginia pine heritability test. A total of 738 trees, representing 123 half-sib families from 12 seed sources were sampled to determine wood specific gravity, extractives and diameter growth. The heritability of diameter growth was .267 while there was no evidence of significant genetic effects on extractive content in juvenile wood. Significant gains in wood production may be obtained using seed source selection for specific gravity and within-family selection for diameter growth; even greater gains may be achieved by among and within-family selection for diameter.

Additional keywords: Specific gravity, extractives

This is the third report about the Virginia Pine (Pinus virginiana) Heritability Study of The University of Tennessee. The first report (Thor, 1964) on wood properties included data obtained during selection of parent trees from which open-pollinated seed were collected for the establishment of the heritability test. A second report (Evans and Thor, 1971) contained heritability estimates and genetic gains for height growth based on 1- and 2-year evaluations. The objective of the present report is to present preliminary results of inheritance of wood specific gravity, extractives and diameter growth in Virginia pine in addition to predicted gains from these heritability estimates.

METHODS

Data used in this study were obtained from one of the six plantations which make up the open-pollinated Virginia Pine Heritability Study. The soil was a silty loam underlain by a fragipan at a depth of approximately 18 inches; the site was relatively flat at an elevation of 1000 feet on the Highland Rim in Middle Tennessee.

During August 1972, when the trees were in their sixth growing season, 11 mm wood cores were collected from 738 trees, representing 123 half-sib families from 12 seed sources. The third and seventh trees were bored in each 10 tree family row-plot in 3 of the 10 replications present. In plots where the third or seventh tree was missing the next tree in line was sampled. Cores with pitch pockets, knots or visible amounts of compression wood were not accepted. Since trees were bored between 12 and 18 inches above ground level this meant that trees which were relatively straight and had a fairly clear bole in this stem section were accepted. Trees under 1 inch in diameter at 1 foot above ground level were not sampled since cores from such trees often crumbled upon extraction. Total height and diameter at half-height measurements used in calculation of volumes and weights of wood per tree were obtained from five year data.

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All cores were extracted with alcohol and benzene for 16 hours followed by alcohol for six hours. Extractives in gm/cm³ were determined by subtracting the specific gravity of each core before and after extraction.

Data were analyzed using the Statistical Analysis System (Barr and Goodnight, 1972) at The University of Tennessee Computing Center. The expected mean squares and the analysis of variance were calculated on an individual tree basis:

<u>Source of variation</u>		<u>Expected mean squares</u>
Replications	2	
Stands	11	$\sigma_w^2 + w\sigma_{f(s)r}^2 + wf\sigma_{rs}^2 + wrf\sigma_s^2 + wr\sigma_{f(s)}^2$
Replications x stands	22	$\sigma_w^2 + w\sigma_{f(s)r}^2 + wf\sigma_{rs}^2$
Families in stands	111	$\sigma_w^2 + w\sigma_{f(s)r}^2 + wr\sigma_{f(s)}^2$
Families in stands x reps	222	$\sigma_w^2 + w\sigma_{f(s)r}^2$
Within plot	368	σ_w^2

The heritability as derived by the variance components method was

$$h^2 = \frac{4\sigma_{f(s)}^2}{\sigma_w^2 + \sigma_{f(s)r}^2 + \sigma_{f(s)}^2}$$

Using parent-offspring regression and correlation the heritabilities were $h = 2b$ and $h = 2r$, respectively. Within-family gains were computed using methods of Falconer (1960) and selection intensity tables of Namkoong and Snyder (1969).

RESULTS AND DISCUSSION

Extracted Specific Gravity

Both replication and stand effects were significant at the 1% level of probability while family within stand effects were only significant at the 10% level. The low family variance component is rather surprising. If, as with other species of southern pines, specific gravity were a strongly inherited complex trait, the family component should be relatively high (Zobel *et al.*, 1972). The low family and high stand mean square are the reverse of the natural variation pattern in Virginia pine where extracted specific gravity had a significant among tree component but was non-significant among stands (Thor, 1964). Apparently specific gravity in Virginia pine is strongly affected by environment with different populations reacting differently to changed environments. The highly significant among replication component would tend to confirm this strong environmental effect.

A New Duncan's Multiple Range Test distinguishing among stand means and the geographic source of each stand is presented in Table 1. The test shows that, in general, the stands can be separated into two groups, those with high wood densities and those with low densities. Stand numbers 2, 12, 9 and 4 fall into the high category and are also the stands which fall into the

extremes of the species range in Tennessee and Kentucky while the five stands with low specific gravity are all from the central part of the range sampled. The coefficients of variation (Table 1) for each stand indicate that the magnitude of wood density variation within stands is approximately equal.

Table 1.--Duncan's New Multiple Range test for specific gravity and coefficients of variation for open-pollinated progeny from 12 stands

No.	Stand Location	Stand Mean	C.V. %
2	West Kentucky (Dawson Springs)	0.41015	5.33
12	Great Valley (Newport, Tn.)	0.40643	5.60
9	Cumberland Plateau (Morehead, Ky.)	0.40544	5.35
4	Eastern Rim (Rock Is., Tn.)	0.40536	5.94
1	West Tenn (Clinton)	0.40250	5.90
13	Great Valley (Elizabethton, Tn.)	0.40237	5.93
10	Great Valley (Etowah, Tn.)	0.39615	4.87
7	Eastern Ridge (Pineville, Ky.)	0.39380	6.62
11	Great Valley (Vonore, Tn.)	0.39356	4.87
8	Cumberland Plateau (London, Ky.)	0.39201	5.92
6	Cumberland Mts. (Wartburg, Tn.)	0.39189	5.99
3	Cumberland Plateau (Sewanee, Tn.)	0.38633	6.65

Heritabilities for extracted specific gravity were estimated at .162 by the variance component method, .129 by the regression method, and .183 by the correlation method. These estimates are low in comparison with values obtained for other species. In the case of the variance components method this result is a reflection of the low family and the high stand variance component. However, the estimates obtained by the three methods seem to be in fairly close agreement. All three methods have their drawbacks as enumerated by van Buijtenen (1962).

Extractive Content

Since the analysis of variance showed a very low and statistically non-significant family effect, no heritability value was computed for this characteristic. The stand component also was non-significant.

The trees in this plantation were in their sixth growing season at the time cores were extracted and heartwood depositions were not expected; therefore, the extractive content should be low. Extractive percent ranged between 2.6 and 10.3% of extracted wood, considerably higher than the 2 to 4% obtained by Zobel et al. (1972) for juvenile wood of loblolly and slash pine, but similar to that produced between the 10th and 25th growth ring in young Virginia pine (Thor, 1964). Virginia pine stands older than 50 years have from 2 to 3 times the amount of extractives observed in younger stands indicating that heartwood initiation is rather late in this species.

Only the replication effect was significant in the analysis of variance, indicating strong environmental control over extractive content. Stonecypher and Zobel (1966) obtained similarly high replication and low among family mean squares for extractive percentages in loblolly pine.

Diameter Growth

Diameter heritabilities were calculated using half-height measurements obtained at age five. Both replication and family mean squares were significant at the 5% level indicating both genetic and environmental control over this character. The heritability estimate of .267 is in agreement with the heritability of diameter inside bark of five-year-old loblolly pine, $h^2 = .28$, as obtained by Stonecypher and Zobel (1966). Variation in diameter growth among stands was not significant.

Correlations among characteristics

Table 2 lists correlation coefficients between various characteristics. The most noteworthy of these is the significant positive correlation between progeny specific gravity and progeny diameter at one foot above ground level, $r = .235$. With the exception of Thor and Brown (1962) who obtained a similar positive correlation for juvenile loblolly pine ($r = .201$) most reports show negative correlations between diameter and wood densities of southern pines. In the present case, although this correlation was significant, only 5.5 percent of the variation in offspring wood specific gravity was accounted for by variation in progeny diameter. By itself, diameter would not be a very efficient indirect selection criterion for high wood density, but it is encouraging that selection for rapid juvenile diameter growth will not result in decreased specific gravity.

A similar situation exists for the correlations between progeny wood specific gravity and the remaining progeny and parent characters. All of these correlations are statistically significant, but none accounts for much of the variation in specific gravity of progeny trees.

Table 2.--Relationships among wood properties of progeny and parent trees

Relationships	Correlation Coefficient
Progeny specific gravity x progeny extractives	.135*
Progeny specific gravity x progeny d.i.b. ^{a/}	.235*
Progeny specific gravity x parent sp. gr.	.091*
Progeny specific gravity x parent extractives	.087*
Progeny extractives x progeny d.i.b.	.078*
Progeny extractives x parent sp. gr.	.025 NS
Progeny extractives x parent extractives	-.053 NS
Progeny d.i.b. x parent sp. gr.	-.083*
Progeny d.i.b. x parent extractives	.010 NS

^{a/} Progeny diameter inside bark data from measurements of core lengths obtained at 1 foot above ground level.

Gains

One objective of most experimental breeding programs is to demonstrate the amount of genetic gain or advance which can be achieved by the program. In the Virginia pine project it was anticipated at the time of initiation that one of the six plantations would be sacrificed for the purpose of creating a seedling seed orchard. This means that the selection intensity used in the calculation of gains will be governed by practical considerations of the spacing desirable in the orchard. The trees in this plantation were planted at a spacing of 4 x 8 feet, each tree occupying 32 square feet. If we assume a desired spacing in our orchard of 30 x 30 feet or 900 square feet per tree, we will rogue about 30 trees for each selected orchard tree.

We may initiate the program by selecting trees from the four stands with high wood density (Table 1), or a proportion saved of 1/3 (this stage is similar to a seed source selection).

The next stage of the selection program is determined by the need to avoid inbreeding. Since a family within each replication is represented by ten half-sib trees in a row plot, only one of these trees can be retained leaving us the final desired number of trees. Selection of individual trees at this within-family level will be for greatest rate of diameter growth. This characteristic is of great economic importance, its heritability is adequate, the within plot variance is large, and the measurement is cheap to obtain.

Mean values of five-year growth and wood density variables with and without stand selection are shown in Table 3. Based on five-year data it is apparent that no gain in yield of wood per tree is achieved by stand selection alone. Although specific gravity is increased by stand selection, it seems to be offset by mild losses in height and diameter. It should be remembered that significant differences among stands were obtained only for specific gravity and not diameter growth. Although there was a positive correlation between wood density and diameter, this correlation was on an individual tree basis; the non-significant correlation between stand means of specific gravity and diameter was negative, $r = -.166$.

Table 3.--Mean values^{a/} for height, diameter,^{b/} wood specific gravity, volume/tree^{c/} and weight/tree with and without stand selection

Source	Ht (ft)	Diam (in)	Sp. Gr.	Vol/Tree (ft ³)	Wt/Tree (lbs)
Mean from four selected stands	9.90	1.48	.4069	.133	3.39
Mean for all 12 stands	10.01	1.51	.3988	.142	3.53

a/ Height, diameter and volume per tree are from five-year measurements.

b/ Diameter outside bark measured at half total height.

c/ The volumes per tree were derived from volume prediction equation of Perry and Roberts (1964), $V = (10.62 D^2 H)/1728$.

The projected gain resulting from within-family selection for diameter growth was .13 inches (with $i = .75$; $\sigma_w = .27$; $h^2 = .267$). Using data from Table 3 this gain in diameter increases the mean volume of wood per tree from .142 to .159 cubic feet per tree after both stand and within-family selection. Adjusting for specific gravity gains from stand selection, the selected trees represent a gain of 14.4 percent or .51 pound of wood per tree.

Although this gain represents increases of both specific gravity and diameter, these data indicate that much greater gains can be achieved by selection for diameter growth than by selection for specific gravity. Of the .51 pound gain in wood per tree only .08 pound was the result of higher specific gravity from stand selection. By using the multistage method of among-family and within-family selection for five-year half-height diameter (Namkoong, Snyder and Stonecypher, 1966), selecting the one third families with best diameter growth and the individual within each family plot with highest rate of diameter growth, a gain of 25 percent over the mean tree weight may be obtained. This gain of .87 pound will result in trees with 4.40 pound of wood per tree.

It should be emphasized that these gains do not take into account height growth changes resulting from among and within-family selection, differential survival of individual families or correlated response of wood density from within family selection (resulting from the positive wood density-diameter correlation). An attempt was made to estimate the correlated response of specific gravity; the resulting response was low and the omission of this response from the gain in weight of wood per tree probably has no measurable effect. However, there was a highly significant phenotypic correlation between family means of height and half-height diameter at age five ($r = .79$). Such a high positive correlation is indicative of a correlated response in height growth from among-family selection and that expected gains are underestimated.

CONCLUSIONS

1. If higher specific gravity wood were the goal of a Virginia pine breeding program, data from this young plantation indicate that most improvement may be achieved by stand selection. Heritability estimates for juvenile wood ranged from .129 to .183.

2. Extractive content in juvenile wood of Virginia pine is primarily influenced by environmental variables. There was no evidence of any significant genetic effect.

3. The heritability of diameter growth (.267) is comparable with heritabilities of other southern pines.

4. A significant positive correlation between extracted specific gravity and diameter growth was indicated on an individual tree basis.

5. A gain of 14 percent in yield of dry wood can be achieved in Virginia pine by a combination of stand selection for wood specific gravity and within-family selection for diameter growth. However, the gain achieved by among and within-family selection for diameter was 25 percent.

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PREDICTED GAINS FOR FUSIFORM RUST RESISTANCE IN SLASH PINE

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Abstract.--Genotype x environment interactions for fusiform rust resistance were observed, but interactions of progenies were unrelated to mean infection levels. Heritabilities of individuals were very low while heritabilities of progeny means were high. Breeding methods utilizing progeny test evaluations or family selection may increase resistance relative to commercial checks by as much as 50 percent.

Additional keywords: Pinus elliotii Engelm. var. elliotii, forest tree improvement, breeding.

Resistance to fusiform rust, Cronartium fusiforme Hedgc. & Hunt ex Cumm., in slash pine, Pinus elliotii Engelm. var. elliotii, is of primary importance to many members of our Program.^{2/} Particularly relevant at this time are predictions of gain by various breeding methods so that maximum improvement in resistance may be achieved.

MATERIALS AND METHODS

Fusiform rust incidence data were taken from field tests five years after establishment. The tests were planted by members of the Program as part of the progeny testing program of seed orchard clones.

Eight open-pollinated progeny tests of Brunswick Pulp and Paper Company (BPP) were utilized (Table 1). Two tests were established per year over a four year period as randomized complete block designs with five replications and seven-tree row plots. Nineteen progenies were common to tests 6 through 11, and a separate group of 19 progenies were present in tests 8 through 13.

Two full-sib progeny tests of Container Corporation of America (CCA) and one of Continental Can Company (CCC) were also used to estimate genetic variances (Table 2). Each test was a RCB with 10-tree row plots; CCA tests had four replications, the CCC test five. Twenty-two crosses from four males and seven females were common to the CCA tests. Two sets of crosses, one consisting of 12 progenies from three males and five females and another with 12 crosses from four males and four females, were used in the CCC test.

Analyses of variance were applied to each test and combination of tests. Each of the open-pollinated tests had sources of variation and degrees of freedom as shown in Table 3. Combined open-pollinated tests had additional sources

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of variation for years, sites and appropriate interactions (Table 4). The analyses of variance for the control-pollinated tests were as presented in Table 5. Male and Female variance components (σ_M^2 and σ_F^2) estimated $\frac{1}{4} \sigma_A^2$, and the male x female variance component (σ_{MF}^2) was an estimate of $\frac{1}{4} \sigma_D^2$.

Table 1.--BPP open-pollinated progeny tests utilized

Test	Year Established	No. of Families	Ave. Fusiform Rust Incidence	
			Families	Checks
			(% infected)	
1-6	1964	35	34	29
1-7	1964	35	23	14
1-8	1965	56	18	8
1-9	1965	56	16	19
1-10	1966	58	32	22
1-11	1966	57	21	15
1-12	1967	46	59	43
1-13	1967	46	58	46

Table 2.--CCA(3) and CCC(4) full-sib progeny tests utilized

Test	No. Males	No. Females	No. Families	Ave. Fusiform Rust Incidence	
				Families	Checks
				(%infected)	
3-6	4	9	29	16	15
3-7	4	11	38	37	32
4-3	7	11	28	70	55

Data presented here were based on rust observations expressed as percent of trees infected per plot. Within-plot variance for a test was estimated by (mean percent infected) x (100 - mean percent infected). Analyses were also performed as described by Becker and Marsden (1972), namely, adjusting the ratio of the number of trees infected to the number of trees per plot and then transforming the adjusted ratio by arcsin of the square root. Through the use of the constant binomial sampling variance, within-plot variances were estimated. Variance components and heritabilities derived by the two methods were virtually identical.

Heritability estimates and predicted gains for various breeding methods were based on procedures outlined by Shelbourne (1969). Individual contributions to genotype by environment interactions were obtained by a method presented by Shelbourne (1972) for partitioning the interaction sum of squares.

Table 3.--Analyses of variance for open-pollinated tests 6 - 13

Source	d.f.	Mean Squares					
		Test: 6	7	8	9	10	11
Reps	4	1424.6**	740.4*	250.4	1030.9*	977.1	274.4
Progenies	18	1045.4**	594.0**	341.4	421.5	620.4	325.5
Error	72	345.1	231.2	248.7	348.4	482.1	216.4
Total	94						
Ave. Infection %		33.1	19.1	16.0	20.9	31.6	16.3
Range of Progeny Means		8.6-66.2	8.4-51.6	0-34.2	0-38.0	5.6-45.4	6.2-92.8
		Test: 8	9	10	11	12	13
Reps	4	262.8	250.7	905.2	523.6*	430.3	496.2
Progenies	18	743.6*	491.6	612.4	800.9**	1252.0**	1138.8**
Error	72	377.1	354.0	403.1	202.3	400.8	435.3
Total	94						
Ave. Infection %		17.8	16.3	32.1	20.9	59.4	58.0
Range of Progeny Means		2.8-48.6	0-35.6	11.4-50.4	0-42.8	25.2-90.4	23.2-83.6

* and ** significant at the 5 and 1% levels, respectively.

Table 4.--Analyses of variance for combined open-pollinated tests

Source	d.f.	Tests 6-11		Tests 8-13	
		MS	σ^2	MS	σ^2
Years	2	2978.8	-22.3	90560.9**	465.8
Sites/Years	3	7220.4**	67.8	2063.4*	16.7
Reps/Sites/Years	24	873.0**	24.8	478.1	6.1
Progenies	18	1214.1**	24.7	2247.1**	48.3
Years x Progenies	36	474.6	5.3	799.5**	26.8
S/Y x Progenies	54	395.0	16.6	397.8	7.1
R/S/Y x Progenies	432	312.0	312.0	363.1	362.1
Total	569				
Ave. Infection %		22.8		34.1	
Range of Progeny Means		14.0-31.5		13.4-51.5	

* and ** significant at the 5 and 1% levels, respectively.

RESULTS AND DISCUSSION

Environments strongly influenced observed rust levels in the combined tests. For BPP tests 6-11, infection levels between sites within years were different (Table 4). In BPP tests 8-13, sites within years were also important, but variation among years was greater. Here, the year to year differences were attributable to tests 12 and 13, which had much higher rust than tests 8-11. However, since the sites were not common across years, the higher rust in tests 12 and 13 cannot be attributed necessarily to yearly variation in rust. The effect may also be due to differing sites. The sites in the two county region of southeastern Georgia where the BPP tests are located do differ (Goddard and Vande Linde, 1967).

Differences among progenies were observed in both combined tests and most individual tests. Segregation of progenies into resistant and susceptible categories was easier in tests with higher rust levels due to greater ranges among progeny means.

Genotype x environment interaction variance components were large relative to the progeny variance component for both combined analyses (Table 4). The Sites/Years x Progenies variance component was considerable for tests 6 to 11, in which variation due to Sites/Years was great. In tests 8 to 13, where variation among years was large, the Years x Progenies interaction was the major interaction component. Apparently, whichever environmental factor is most influential will be the source of most interaction with progenies. The overall magnitude of interaction components indicates that selection of resistant progenies may depend on particular environmental conditions.

The above interactions of the open-pollinated progenies were unrelated to their mean infection levels. Correlations between infection percentages and Years x Progenies and Sites/Years x Progenies interactions were .04 and .26 for Tests 6-11 and -.19 and .38 for Tests 8-13. Variation of resistant progenies from test to test seems comparable to that of susceptible progenies.

Furthermore, the correlations between Years x Progenies and Sites/Years x Progenies interactions were .13 and .03, respectively, for the two combined tests. No apparent advantage would result from testing progenies over several sites per year as compared to testing on fewer sites per year over several years.

Specific crosses among genetic lines may offer no more resistance to disease at high levels of infection than general crosses. Table 5 shows that the magnitude of the Male x Female variance component decreased as infection rates increased. Further indication of the relative lack of dominance genetic variance at high levels of infection is the nonsignificance of Testers x Clones interaction in progeny tests with 90+ percent rust (Weir and Zobel, 1972).

Narrow-sense heritabilities tended to increase with rising infection rates (Table 6). Correlations among heritabilities of individuals and infection rates exceeded .4, while for heritabilities of progeny means, the correlations were about .35. The positive trend was evident up to the maximum infection rate in the present study, 70 percent.

Individual tree selection will not be a productive method of increasing resistance, based on the low heritabilities for individuals noted here, usually

Table 5.--Analyses of variance for full-sib progeny tests

Source	d.f.	3-6		3-7	
		MS	σ^2	MS	σ^2
Reps	3	327.95		252.04	
Males	3	965.95*	33.20	1678.21*	78.21
Females	6	358.90	9.04	2050.30*	164.88
Males x Females	12	245.48	17.75	-19.00	-93.82
Error	63	174.18	174.18	450.08	450.08
Total	87				
Ave. Infection %		16.1		35.2	

Source	d.f.	4-3	
		MS	σ^2
Reps	4	422.60	
Progenies	23		
Sets	1	10,603.20*	
Males/Sets	5	4,928.45**	306.96
Females/Sets	7	906.05**	79.61
Males x Females/Sets	10	-136.44	-82.58
Error	92	193.86	193.86
Total	119		
Ave. Infection %		69.5	

* and ** significant at the 5 and 1% levels, respectively.

Table 6.--Relationship of heritability to infection level in open-pollinated tests

Test	h^2		Ave. Infection %
	Individual	Progeny Mean	
Tests 6-11:			
6	.238	.670	33.1
7	.181	.611	19.1
8	.052	.271	16.0
9	.035	.174	20.9
10	.048	.223	31.6
11	.052	.335	16.3
Combined	.054	.623	22.8
Tests 8-13:			
8	.173	.493	17.8
9	.074	.280	16.3
10	.073	.342	32.1
11	.277	.747	20.9
12	.262	.680	59.4
13	.213	.618	58.0
Combined	.083	.685	34.1

less than .1. At high infection rates with concomitant higher heritabilities and more reliable identification of resistant trees, gains by individual selection would be greater but still not appreciable.

The original field selections made for BPP provide an example for the response resulting from phenotypic selection. Most of the trees were taken from stands with less than 30% rust infection, and, consequently, selection intensity was low. With heritability also low, the theoretical gain in resistance is minimal, about 9.4% relative to commercial checks. Realized response from BPP's clonal orchard has been a -28.2%; realized gains have not matched the expected. Similar responses from original selections have been observed for other companies.

While heritabilities for individuals were low, heritabilities of progeny means were high, often exceeding .6 (Table 6). Thus, progeny testing identifies genetic variation existing for rust resistance, and breeding methods relying on select tree evaluation via progeny testing should result in appreciable gains in resistance.

Roguing established clonal orchards, or establishing reconstituted orchards, is an expedient method of increasing rust resistance. In the case of BPP, and most cooperators in the Program, roguing of existing orchards allows recouping of the resistance lost in the first generation selections, and more. Specifically, BPP is establishing a new orchard including their top 31% resistant clones (25 of 81), and an improvement of as much as 28% over commercial checks could result.

While long-term efforts to capture specific combining ability for resistance appear unnecessary, short-term utilization of certain specific crosses showing exceptional resistance has potential. In fact, a number of biclonal orchards, with resulting seed being bulked, is a fast method of increasing resistance. Assuming no dominance genetic variance and an infection rate of 35%, production of specific progenies could result in an infection level of 14%, or a 45% improvement relative to the checks.

A seedling seed orchard composed of bulked open-pollinated progenies has been established by Buckeye Cellulose Corporation (BCC). Seed was collected from 50 clones in each of two orchards - BCC and University of Florida (UF), bulked by orchard, and planted in alternate rows. Subsequent thinning will retain one tree in an interval of 10. Separate rust evaluations indicate that the BCC clones contributed were more resistant than the UF clones. Observations in the orchard show 35.2% infection for the BCC progenies and 54.2% for the UF lines. Estimated gains from thinning are 2.4% for BCC and 8.2% for UF, or, assuming that the orchard production will be the average of the two, the total gain may reach 3.5%, an 8.2% gain relative to checks lots. This relatively low improvement is due to the inability to identify individual clone contributions (a consequence of the bulking of seed) and the high susceptibility of UF clones.

A full-sib seedling seed orchard is under development by BCC, and substantial improvement in rust resistance is expected. Twelve tested highly-resistant males in the Program are being crossed with eight known resistant females from the BCC orchard according to a factorial mating system to produce

96 full-sib families. Rust infection at the orchard site is expected to be about 50%. At that assumed infection level, our data suggest minimal dominance genetic variance will exist. Families will be rogued to approximately the best one in 10, and one tree in a row-plot of 10 in the selected families will be retained. Most of the gain to be realized from this orchard will result from the selection of families with a small increment coming from within-family selection. Total gain may reach 55% relative to commercial checks.

A seedling seed orchard consisting of open-pollinated progenies of 50 of the more resistant clones in the Program is being established by St. Joe Paper Company. The orchard will be thinned to the best 20 progenies and the best tree in a 10-tree row plot. Seventy percent infection at the site is expected. Total gain of 30% relative to commercial checks is anticipated.

The responses predicted here suggest that fusiform rust impact on slash pine management can be appreciably reduced if appropriate breeding programs are followed. Adequate progeny testing is essential in order to identify good general combiners. Employment of these good general combiners in subsequent breeding may lower infection levels by as much as 50%.

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LOCATION DIFFERENCES AND THEIR INFLUENCE ON HERITABILITY ESTIMATES
AND GAIN PREDICTIONS FOR TEN-YEAR-OLD LOBLOLLY PINE

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Abstract.--Heritability estimates and predictions of gain from simple mass selection among 75 ten-year-old, open-pollinated families of loblolly pine growing in two locations indicated that the influence of location differences varied according to the trait under consideration. Values differed between locations, but no more than would have been expected from published reports. Estimates and predictions from combined data, however, indicated substantial upward bias arising from interactions between locations and families in some of the separate location values. Biases were apparently more serious for tracheid length, diameter, volume, and dry weight than for specific gravity and "cronartium score" (an index of fusiform rust infection).

The existence of substantial bias for some traits emphasizes the fact that heritability estimates and gain predictions from single location tests must be used with caution since they may be too high for valid application to a broad range of locations. Estimates of realized gain from single locations should also be liable to this same type of bias.

Numerous published values for heritability and gain exist for a wide variety of traits in a number of forest tree species. Many of these reports, however, are from tests planted in only one location. Values derived from single location tests are biased upwards because estimates of genetic effects from these tests also contain the effect of interactions between the genotypes and the particular location involved. Estimation and removal of these interaction effects can only be accomplished by evaluating the genotypes in more than one location (Comstock and Moll, 1963; Namkoong *et al.*, 1966). The magnitude of this bias will vary according to the trait, genotypes, and location involved and may, in some instances, be small enough to have no practical influence.

Similar biases result from the failure to adequately sample year effects. However, as Squillace (1969) has hypothesized, interactions between year effects and forest tree genotypes can be expected to be smaller than interactions with location effects, especially for those traits evaluated late in the life of an individual. The long span of time involved for the expression of these traits should cause year-to-year influences to average out for plantings made in different years. Year effects may, of course, be more important for traits such as survival which are more strongly influenced by extreme environmental fluctuations.

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The current study was designed to investigate one facet of this problem by examining the nature and relative magnitude of the influence of differences between two locations on estimates of heritability and predictions of gain from simple mass selection for merchantable ten-year-old loblolly pine (Pinus taeda L.) from unselected parents.

MATERIALS AND METHODS

The trees evaluated for this study were from a portion of the Loblolly Pine Heritability Study, a cooperative venture of International Paper Company and North Carolina State University. Details of the objectives, design, and implementation of the heritability study have been given by Stonecypher (1966); therefore, only a brief description of that portion directly involved in the current investigation viz., the open-pollinated study, will be given here.

OPEN-POLLINATED HERITABILITY STUDY

The open-pollinated study was initiated in the fall of 1959 by collecting wind-pollinated cones from 387 of the 390 parent trees originally selected as a basis for the heritability study. These parent trees were chosen at random from a natural stand of loblolly and shortleaf (Pinus echinata Mill.) pine resulting from seedfall onto abandoned agricultural land. Two restrictions were imposed on the completely random selection of parents: trees which were not producing female strobili or which were judged unsafe to climb were rejected. The chief danger to climbers was the presence of severe bole galls caused by fusiform rust (Cronartium fusiforme Hedc. and Hunt ex Cumm.). Biases in favor of fecundity and against susceptibility to fusiform rust were thereby introduced, but were slight since less than one percent of the original random selections were rejected.

Of the 387 seed lots originally collected, 280 yielded sufficient seedlings for field planting. These 280 families were divided at random into ten sets, each with 28 families, to reduce field block size. Field plantings consisted of two replications at each of two locations. The two planting locations were only five to six miles apart, but were comprised of quite different soil types. Sets were randomly located within each replication and the positions of 25-tree square family plots within sets were also randomly assigned. A map detailing the location of the various portions of the heritability study, including the plantings investigated in the present study was presented by Stonecypher et al. (1973).

SAMPLING PROCEDURES

In the summer of 1970, five sets were randomly selected for thinning with a modified mechanical-selection thinning regime. The entire fifth row in each plot was marked for removal to serve as an access row. Additional trees were marked on each plot so as to leave 12 trees by first marking all individuals which appeared unlikely to survive or make a useable tree at maturity, e.g., forked, broken, suppressed, and severely infected trees were marked. Any additional trees were chosen for removal on the basis of spacing considerations.

After marking was completed, 15 families per set from one replication at each location were chosen at random from among those families having at least five "crop" trees marked for removal in both locations. Crop trees were individuals which would normally be utilized for pulpwood during an operational thinning, i.e., all forked, broken, excessively diseased, or extremely small individuals were rejected. These five crop trees from each plot comprised the sample from which estimates of heritability and predictions of gain were made. Sample trees were therefore better than the average individual removed during thinning, but were more representative of the merchantable component of each plot.

Each sample tree was evaluated for diameter at breast height, fusiform rust infection, unextracted specific gravity, tracheid length, total inside-bark volume, and total inside-bark dry weight. Fusiform rust infection was assessed through application of a subjective scoring system, ("cronartium score"), which assigns to each tree a score ranging from 1 to 10 with increasing severity of rust infection. Determinations of specific gravity and tracheid length were performed by the laboratory staff of the North Carolina State University-Industry Cooperative Tree Improvement Program. Volumes were calculated using prediction equations developed separately for each location from downed-tree measurements of an independent sample of trees. Dry weights were calculated for each tree from these volumes and their associated specific gravity. Measurement procedures have been described in greater detail by Barker (1973).

STATISTICAL PROCEDURES

Analyses of variance and covariance were conducted for each of the six traits under consideration. Analyses were performed for each location and also for data combined from both locations. Expected mean squares for the analyses were derived assuming a random effects model (Eisenhart's (1947) Model II).

Components of variance from these analyses were used to calculate estimates of narrow-sense heritability (on an individual plant basis) for each trait in each location and for combined locations. Each heritability estimate was combined with its associated estimate of phenotypic standard deviation and an arbitrarily chosen intensity of selection to yield predictions of the progress to be expected from simple mass selection among the parent trees. An intensity of selection corresponding to selecting one percent of the population ($i = 2.6652$) (Namkoong and Snyder, 1969) was employed for all traits except cronartium score. Predictions for this trait were derived for the case where only 50 percent of the population was selected ($i = 0.7979$) since, in most cases, only about one-half of the trees in a given family will be infected and selection for resistance consequently cannot be more intense.

RESULTS AND DISCUSSION

Single location estimates of narrow-sense heritability indicated that cronartium score is under moderate additive genetic control and that dry weight, volume, diameter, and tracheid length are under moderate to strong control while specific gravity is under relatively strong control. Predictions of genetic response to selection did not exactly reflect the relative

magnitudes of the heritability estimates since, in some cases, greater levels of phenotypic variability tended to overcome lower heritability estimates. Gain predictions were generally of sufficient size to indicate worthwhile progress from selection directed towards improvement of these traits.

Results from the separate location analyses and estimations were, therefore very much as would be expected. Some heritability estimates and gain predictions did exhibit a rather wide divergence from location to location for the same trait, but these differences were not much larger than those reported in the literature and could be expected from the different levels of environmental variation existing in each location.

Many of the published reports of heritabilities and gains were based on information from populations which had undergone at least one cycle of selection for various traits. Estimates reported here are from an unselected population with the restriction of merchantability placed on those trees included in the analyses. This restriction undoubtedly had an influence on the resultant variation both within and among families, especially for cronartium score where a definite bias was introduced by discarding all severely infected trees. Similar biases for diameter, volume, and dry weight can also be expected from the omission of extremely small individuals. Lack of perfect correspondence with other reports can therefore be expected. What is surprising is that the estimates agreed with these reports as closely as they did.

The most interesting implications from the current study center upon the results obtained from the combined analyses and their lack of agreement with separate location estimates. For several traits, evidence was found for the existence of a substantial degree of location influence on estimates of heritability and response to selection. The nature and magnitude of these influences were not constant, but varied according to the trait under consideration.

Two general situations were found to exist with regard to the influence of location differences. For the first group of traits, heritability estimates and gain predictions were different between locations, some more so than others, but estimates from the combined data were intermediate, both for gain and heritability. For the other group, location differences were still evident, but combined location estimates were substantially lower for these traits.

Location differences in the first situation arose from the existence of differential levels of phenotypic variability in each of the locations. Family components of variance remained relatively constant from location to location with the larger environmental variation for one location resulting in a lower estimate of heritability for this location. When data were combined from both locations, family variation remained relatively unchanged and phenotypic variation tended to average out, resulting in an intermediate heritability estimate. That location differences can be expected to occur has been pointed out by Falconer (1960) and many other authors when they caution that heritability estimates are the property not only of a character, but also of the genetic sample and the environment to which it has been subjected.

Implications from the second situation are far more important, for it is in these instances that the existence of a substantial degree of family by location interaction is indicated. Separate location estimates for these traits differed for the same reason indicated above, but the lower estimates from the combined data were due not to a greatly increased level of environmental variation but to a reduction in the magnitude of the genetic variation. This reduction in genetic variation resulted from separate location estimates being biased upwards because they contained the variation due to interactions between those particular families and that particular location under consideration. Interaction variation is inextricably bound to the genetic variation estimated from single location tests. Its estimation and removal can only be accomplished by evaluating those families involved in more than one location.

For the families and locations investigated in the current study, two traits, unextracted specific gravity and cronartium score, typified the situation where combined results were intermediate to separate location estimates. Estimates of heritabilities exhibited noticeable differences between locations with estimates of 0.67 and 0.98 for specific gravity and 0.11 and 0.35 for cronartium score. Combined location estimates for these traits, 0.76 and 0.23, respectively, were both intermediate to the separate location estimates (Figure 1). Gain predictions were similarly affected with predictions of 12 and 17 percent of mean specific gravity and 21 and 75 percent of mean cronartium score. Combined predictions of gain (13 and 48 percent of the mean, respectively) were also intermediate to their corresponding separate location estimates (Figure 2). Interactions between families in sets and locations were found to be statistically nonsignificant for the analyses of variance for both of these traits.

The other four traits (tracheid length, diameter, total volume, and total dry weight) yielded combined estimates which were considerably lower than separate location estimates. Heritabilities for these traits were also different from location to location with diameter (0.36 and 0.60), volume (0.40 and 0.56), and dry weight (0.39 and 0.55) yielding estimates agreeing more with each other than with those for tracheid length (0.31 and 0.99). Combined location estimates for these traits were not intermediate, but were substantially smaller than either separate location estimate. Combined location heritability estimates were 0.21 for diameter, 0.20 for volume, 0.19 for dry weight, and -0.06 for tracheid length (Figure 1). The negative estimate for tracheid length was due to the existence of a negative estimate for the family component of variance (-0.0009) from the combined analysis for this trait. In light of the relatively large standard error (0.0024) associated with this estimate, it is reasonable to assume that neither the component nor the heritability differed significantly from zero.

Gain predictions from the combined data were also considerably smaller than separate location predictions. Predictions from separate locations did not follow the same patterns exhibited by heritabilities from these locations, with gain for volume (48 and 45 percent of mean volume) and dry weight (48 and 44 percent) much larger than that for diameter (20 and 22 percent). Heritabilities for these three traits were of essentially the same magnitude. The larger gain predicted for volume and dry weight resulted from a higher level of phenotypic variability for these traits relative to that for diameter. In addition, gain predictions for these three traits agreed much more closely

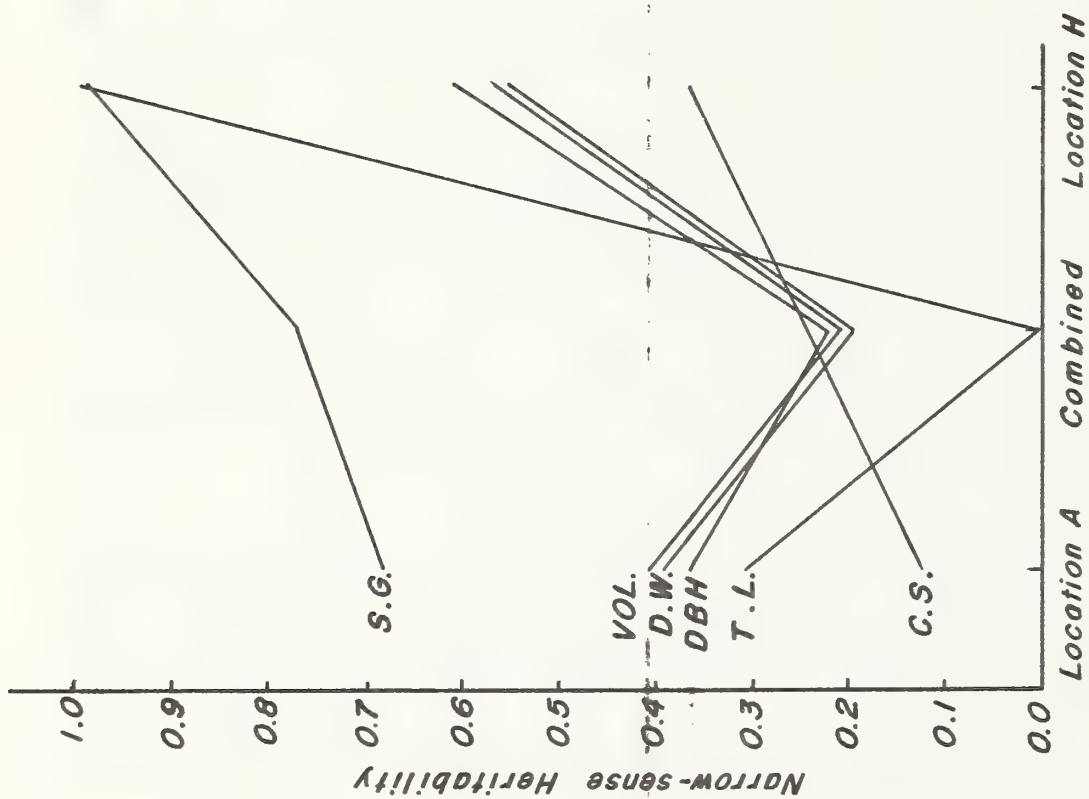


Figure 1. Narrow-sense heritability estimates for separate and combined locations.

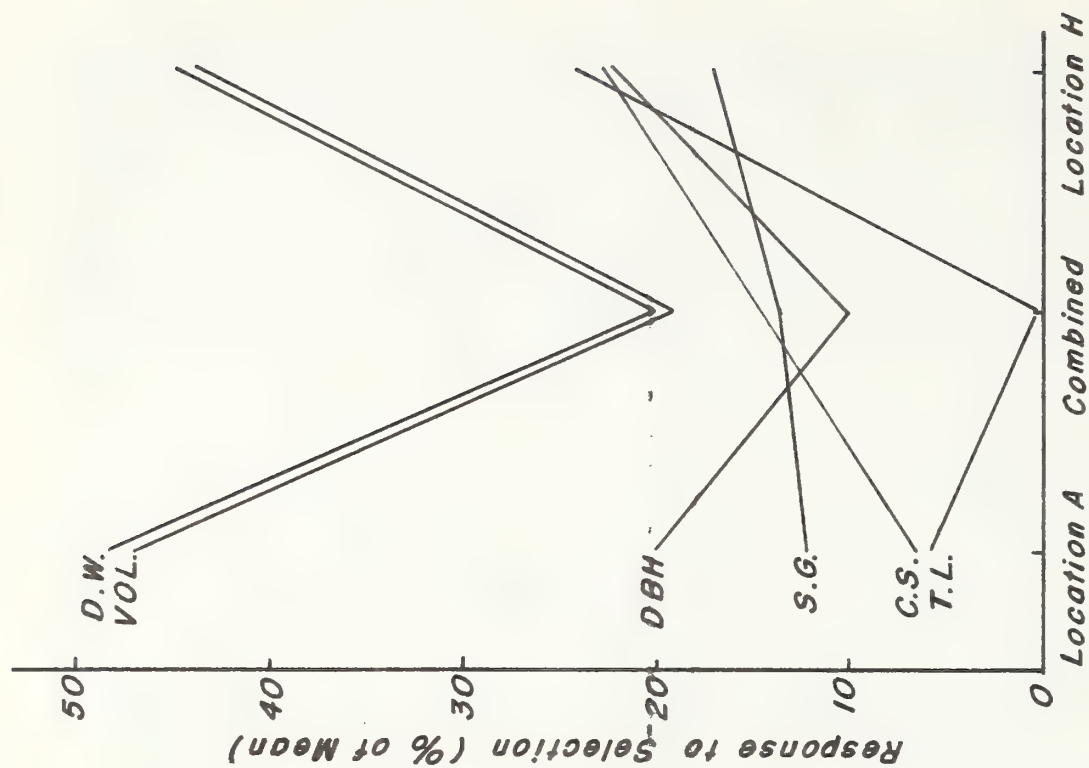


Figure 2. Predictions of gain from simple mass selection for separate and combined locations.

between locations than their heritabilities would indicate. This closer agreement was due to locations with lower heritabilities having a relatively higher phenotypic variation. Separate location gain predictions for tracheid length (five and 26 percent of mean tracheid length) were in closer agreement to their corresponding heritability estimates.

Predictions of gain for these traits from the combined data, like combined heritability estimates, were substantially smaller than either of their separate location predictions. These combined predictions were 20 percent of mean volume, 19 percent of mean dry weight, 10 percent of mean diameter, and minus one percent of mean tracheid length (Figure 2). The negative prediction for tracheid length is again probably not significantly different from zero. For the first three traits, gain predictions were approximately one-half of that predicted for each location. Interactions between families in sets and locations were found to be statistically significant for all four traits.

CONCLUSIONS

It is apparent from the current study that location differences can have considerable influence on the magnitude of heritability estimates and gain predictions. Estimates from single location tests, while applicable to the particular location tested, are biased upwards to the extent that an interaction between the genotypes and the location actually occurs. This interaction will cause a similar bias in estimates of mean performance and will thereby result in estimates of realized gain which are also biased.

If enhanced family differences arising from this interaction are to be utilized for increased genetic gains, planting zones must be delineated so as to include those locations favorable for the selected genotypes. If, on the other hand, a group of genotypes with broad adaptability for several locations is to be selected, the interaction variance can no longer be "captured" and must be removed from heritability estimates and gain predictions by including all locations of interest in tests designed to provide these estimates. The amount of this bias varies depending on the trait under consideration and gain predictions may be less drastically influenced than heritability estimates.

If similar location effects exist for other populations, many of the heritability estimates and gain predictions which have been reported from single location tests can be expected to be too high for valid application to a broad range of locations. Future studies designed to provide similar estimates should include an adequate sample of locations of interest as well as genotypes if these estimates are to have broad applicability. The importance of including all locations of interest in these tests or the delineation of planting zones is apparently more crucial for some traits than for others.

Results from the current study are admittedly based on a biased sample. Further investigations on the effects of location (and year) differences should be made involving genotypes which more closely represent actual situations. A more extensive evaluation of location effects on the inheritance of non-destructively sampled traits is currently planned for the entire heritability

study. The large number of progeny tests which include both year and location replication should yield much valuable information on interaction influences as they reach a meaningful age, even though they were not designed specifically for variance component estimation.

Until estimates based on adequate samples of years and locations become available, separate location and year estimates will, of course, have to serve. They should, however, be used with caution since realized gain for a broader range of locations and years can be expected to be somewhat less than that predicted from these single location estimates.

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15-YEAR GAINS FROM PARENTAL AND EARLY FAMILY SELECTION IN LONGLEAF PINE

E. Bayne Snyder¹

Abstract.--Wind-pollinated families from 100 parents differed greatly in height at age 8. Selection of the tallest 10 percent produced a 43-percent gain in plot volume at age 15. Most of this gain was attributed to better survival of taller families rather than to differences in growth of survivors. Selection of the fastest growing 25 percent of the parents produced a 15-percent gain in 15-year plot volume. Progeny testing for early height growth prior to orchard establishment is advisable.

Additional keywords: Genetic gain, progeny test, height growth, survival, volume, juvenile performance, Pinus palustris.

Wide differences in early growth of longleaf pine (Pinus palustris Mill.) families were demonstrated by an 8-year progeny test (Snyder 1969). Some families averaged 10 feet tall, nearly twice the population mean, while others averaged less than 1 foot tall. The study planting was remeasured at age 15, and the gains from parental selection and from selection of 8-year-old families are reported here.

METHODS

In 1955, 100 trees were randomly selected in Harrison and two adjacent counties in Mississippi. In 1957, their open-pollinated progeny were bar-planted on a grassy site at 6- x 12-foot spacing. Eight-tree row plots were replicated six times. Brown spot was controlled by spraying. Details on planting and care were reported earlier (Snyder 1969).

In 1972, heights, d.b.h.'s, and other traits were measured and subjected to analysis of variance for randomized blocks with missing plots. Trees not tall enough to have d.b.h.'s were not measured. Survivals were transformed to arc sine $\sqrt{\text{percentages}}$. Volumes were computed according to Schmitt and Bower (1970). Statistical significance was tested for at the 0.05 level.

RESULTS

Family selection

Family differences in height were still significant at 15 years, but they were considerably smaller than at 8 years. Differences in diameter, volume per tree, survival, and volume per plot were also significant.

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By selecting the tallest 10 percent of the families at age 8, a 43 percent gain was obtained in 15-year plot volume (6.7 vs. 4.7 feet³) (table 1). The correlation between 8-year mean heights and 15-year mean volumes per plot was 0.76. Surprisingly, height growth is not responsible for the increased plot volumes according to the following analyses.

Table 1.--Gains realized at age 15 years from selecting the best 10 percent of the families at 8 years

Trait	Mean		Gain
	Selections	Population	
	-----Ft. or ft. ³ -----		Percent
8-year height	8.9	5.8	--
15-year height	30.7	29.3	5
15-year volume/tree	1.57	1.38	14
15-year volume/plot	6.70	4.69	43

Selecting the tallest 10 percent of the families at 8 years resulted in a 33-percent gain in survival at age 15; 8-year heights had a -0.75 correlation with relative mortality, (8-year survival minus 15-year survival) / 8-year survival. Thus, gains in volume per plot were achieved mainly through survival gains, whereas the usually multiplicative effects of improved height and diameter growth were minor. Mean survival in 1965 was 59 percent but by 1972 had decreased to 39 percent. Many seedlings that were less than 1 foot tall at age 8 died. Brown-spot was not controlled between ages 8 and 15. Also, short seedlings were not tallied in 1972.

The correlation between early and later family heights was only 0.57, and selection of the tallest 10 percent of the families for height at 8 years produced only a 5-percent height gain at 15 years. Mortality and the omission of numerous slow growing individuals are responsible for the poor correlation.

Similarly, selecting the best 10 percent achieved only a 5-percent gain in diameter. This trait therefore contributed little more to variation in volume per plot than did height growth.

Parental selection

The 8-year height gain from selecting the best 25 percent of the parents was previously reported as 12 percent (Snyder 1969). By 15 years the gain was only 3 percent (table 2). Thus, the height gains from parental selection

for height have also deteriorated. The decline is caused by the reduced height variance among the 15-year-old families rather than reduced heritability since the latter has remained about the same. In 1965, h^2 was 0.48 ± 21 , and in 1972 it was 0.51 ± 20 . Heritabilities were calculated from correlations between parental height/age ratios and progeny mean heights.

Table 2.--Gains realized at age 15 years from selecting the best parents

Trait	Mean		Gains
	Selection	Population	
	-----Ft. or ft. ³ -----		<u>Percent</u>
BEST 10 PERCENT			
Parental annual height	2.19	1.84	--
8-year height	6.2	5.8	7
15-year height	30.6	29.3	4
15-year volume/tree	1.44	1.38	4
15-year volume/plot	4.80	4.69	2
BEST 25 PERCENT			
Parental annual height	2.10	1.84	--
8-year height	6.5	5.8	12
15-year height	30.1	29.3	3
15-year volume/tree	1.50	1.38	9
15-year volume/plot	5.38	4.69	15

The gain in plot volume, however, from selecting the fastest growing 25 percent of the parents was 15 percent. Therefore, height growth of parents is a poorer guide to later than to early progeny height, but is satisfactory for obtaining gains in later plot volume. As in the early report of this test (Snyder 1969), it can be concluded that some gain is realized from parental selection but considerably more by family selection. At 8 years the gains from parental and family selection were 12 and 35 percent for height; at 15 years they are 15 and 43 percent for volume.

DISCUSSION

General results similar to those of the present experiment were obtained in a less rigorous 72-parent experiment (Snyder 1961). At 7 years mean height was 7 feet; at 12 years, mean survival was 51 percent and mean height was 30 feet. Height at age 7 was correlated with 12-year height ($r = 0.60$), relative mortality ($r = -0.65$), and plot volume ($r = 0.76$). Selecting the tallest 10 percent of the families at 7 years (mean height = 12 feet) resulted in gains at 12 years of 10 percent in height growth but 69 percent in plot volume.

Advisability of postponing orchard establishment until parents are progeny tested depends partly on the length of time required for reliable testing. In this and the previous report (Snyder 1969) progeny tests were evaluated at 8 years because by that age within-plot heights are more uniform ($h^2 = 0.53$) than at 5 years ($h^2 = 0.12$). For practical selection, however, 5-year plot means would serve equally well. The best families had exactly the same rank, and the correlation between family means in the two years was 0.78. Planting described here were on an infertile, grassy site. Where competition is controlled or sites are fertile, reliable results might be obtained in less than 5 years (Goddard, et al. 1973).

Would it pay to limit progeny testing to parents rated plus for growth? Though the current experiment contained no plus trees, the random sample of 100 parents provided a range in parental height/age ratios of from 1.1 to 2.6 feet per year. Based on 8-year results, I recommended relaxing parental selection for height/age to 70 percent, i.e., discarding only 30 percent and progeny testing the rest (Snyder 1969). To further decrease the proportion selected would have decreased the chances for obtaining rare, superior growing families. This recommendation also holds for current 15-year plot volumes. Because superior genotypes often could not be recognized from parental performance, reducing parental selection from 25 percent to 10 percent reduced gains from 15 to 2 percent instead of increasing them (table 2). Moreover, Goddard, et al. (1973) found little difference in the likelihood of fast-growing families whether parents were plus trees or merely good-quality trees. Thus, there is no evidence that intensive parental selection of longleaf for growth rate in wild stands would pay.

Although brown spot was chemically controlled in these plantings, a similar pattern of variation in height growth has been observed where the disease was not controlled (Snyder and Derr 1972). The findings therefore should apply whether brown spot is a problem or not.

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SECOND GENERATION SELECTION WITH PROBABILITY PROPORTIONAL TO PREDICTION

Ray K. Strickland^{1/}

Abstract.--Probability proportional to prediction (3-P) sampling has been used increasingly in forestry during the past ten years. In progeny tests, ranking families from best to poorest for the many traits under consideration on the basis of total enumeration, is cost prohibitive; a less expensive system of subsampling is essential. Second generation selection using 3-P subsampling is ideal for this purpose. The generation methods discussed should be applicable to both coniferous and hardwood tree improvement programs.

Additional keywords: Forest tree improvement, family selection, probability sampling.

INTRODUCTION

In the southeast, progeny tests are beginning to be utilized as sources of selection material for our next generation of seed orchards. We often attempt, initially at least, to make inferences concerning relative merits of progeny lines on the basis of total enumeration of all the trees for all the characteristics in which we desire to make genetic gains. It soon becomes obvious, however, that this degree of quantification is cost prohibitive so we begin to consider possible methods of subsampling.

One possibility is to sample every other, every third, etc. tree in each plot in each block (systematic sampling) and use this information to rank our families. Or, perhaps a random sample of a fixed number of trees within each plot would work just as well. Many such sampling schemes of varying intensity and degree of randomness could be employed and might do a satisfactory job of identifying the families from which to select our next generation of breeding trees.

One method utilizing 3-P requires total enumeration of progeny tests for one or perhaps two characteristics, usually disease and/or volume. The remaining traits are sampled only on those lines whose values and/or volumes surpass a certain established minimum, usually check average or some percentage above that. Finally, the individuals within the lines chosen for subsampling are selected with probability proportional to their size or value. Another possibility, which would reduce field work, would require only an estimated population mean and number of trees following a cursory examination of a progeny test.

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PROCEDURAL METHODS

Grosenbaugh (1963) introduced probability proportional to prediction sampling to forestry. Two approaches using the technique for second generation selection are developed here. Other feasible approaches may also be evident for particular needs.

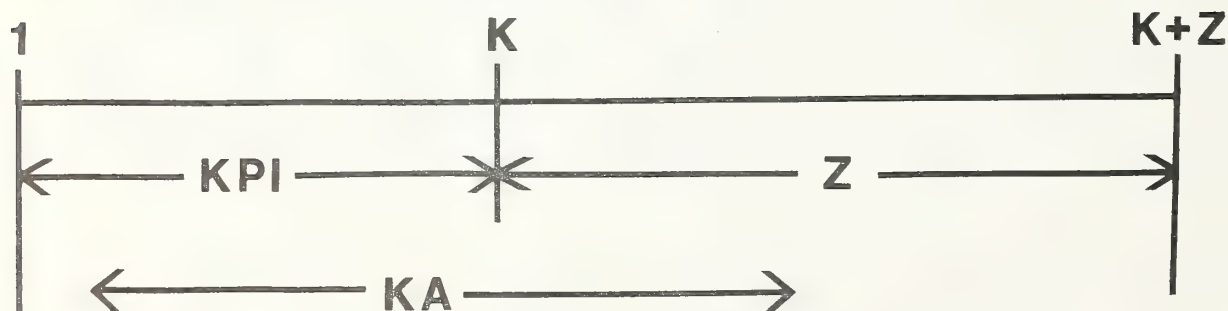
Suppose you have a progeny test that you wish to subsample but have no list or previous measurement information on hand. For simplicity we'll assume we have little or no disease but if it is a problem, total enumeration for disease is necessary. A cursory inspection of the progeny test is essential to estimate \bar{y} , the average tree size, \hat{N} , the estimated number of surviving trees and \hat{K} , the largest expected tree. The size of the subsample, n , needed to properly quantify the families within the progeny test must then be estimated. Usually an average of 15 to 20 trees per family is adequate for a relative rating. A random number generator that is known to be unbiased is needed to produce the 3-P list for field subsampling. The group of random numbers generated, Z , that are in the range from \hat{K} to $\hat{K} + Z$ and are defined as "nulls" since they are greater than any of the expected observations in the test. The number $\hat{K} + Z$ which is put into the computer to produce the appropriate random array is calculated in the following manner:

$$\hat{K} + Z = \frac{(\hat{N})(\bar{y})}{n} = \frac{\hat{T}}{n} \quad (1)$$

where \hat{T} is the estimated population total.

A random array dimensioned to the same size and layout as the progeny test is generated using the numbers from 1 through $K + Z$ with replacement (Figure 1). Since the values for K and T may be obtained by estimation or actual measurement, Figure 1 is developed as with actual values. KPI is the random range of sizes or values from 1 through K which corresponds directly to the expected tree sizes or values in the progeny test. The "nulls" are randomly distributed in the array depicting the progeny test and those trees associated with a "null" are not considered for subsampling unless they fall into the "sure to be measured" category. An adjustment, KA , can be made to make K larger or smaller than the actual largest or most valuable tree. If KA is made smaller than K , those individuals in the test that fall in the range between KA and K are "sure to be measured" trees (i.e. they have a probability of 1 of coming into the subsample). On the other hand, if KA is made larger than K , no individual has a probability of 1 of being in the subsample. No adjustment in KA means it is left equal to K .

Figure 1.--The 3-P sampling system depicted as points along a line. Explanation is as detailed in the text (above).



Other than designated "sure to be measured" trees, only individuals in the KPI range are considered for subsampling. If the size or value of a non-"null" tree in the KPI range is equal to or greater than the associated volume or value in the random array, it is designated for subsampling for all the characteristics.

The other procedure proposed assumes total enumeration for disease and size or value. With this approach we can eliminate families that do not meet specified standards relative to level of infection and size or value. Also, trees within retained lines that are diseased are eliminated as subsample candidates. The purpose is to rank the remaining families from best to poorest. The same procedure is used except we know T, the sum of the retained individuals, and K, the largest tree, because we have measured it. Therefore, the equation for $K + Z$ is changed slightly to:

$$K + Z = \frac{\sum_{i=1}^N Y_i}{n} = \frac{T}{n} \quad (2)$$

where N is the number of individuals within retained families and n is the number of observations desired in the subsample as before.

Subsequent to total enumeration, where the arrays relative to disease and size are in the computer, the generated random array is compared to the retained size array. Those non-"null" individuals that are larger than or equal to the random array KPI's are designated by the number 1 and all others (i.e. "nulls" and individuals smaller than KPI) are designated 0. This gives the position in the field of those individuals to be subsampled for the other characteristics of interest. Actually, the size and disease arrays used for selection purposes can come from previous measurements as well as from current data. Consider as an example slash pine, Pinus elliottii Engelm. var. elliottii, in a high risk fusiform rust, Cronartium fusiforme Hedgc. & Hunt ex Cumm., area. Rockwood and Goddard (1973) found that selection of progeny lines, rather than individual trees, for rust resistance gave the best results. Those lines with highest rust incidence should be eliminated as second generation prospects for utilization in any moderate to high risk fusiform rust area. Also, rarely should a second generation candidate with rust be accepted, even for planting in a low risk area.

DISCUSSIONS AND CONCLUSIONS^{1/}

The 3-P subsampling techniques for second generation selection are simple and quite easy to apply. Our purpose is to designate those families within a progeny test that are acceptable as parental families for our next breeding generation. We are generally interested in visiting only the best two or three families within a progeny test to make individual tree selections. The techniques outlined here place major emphasis on freedom from disease and/or size or value. Secondary emphasis is then placed on other traits such as straightness, form, wood quality, branching, etc., as deemed appropriate through a normal selection index procedure.

^{1/}Further information, including the selection program and an example, may be obtained from the author. The computer program is in APL.

This procedure does not work as well on small progeny tests containing less than about 1,000 trees after diseased trees are eliminated. Actually, the larger the test (within limits of reasonable statistical design) the better the technique works. For example, 300 to 400 subsample trees seem adequate to array the families in a 20 to 25 line test with ten replications (i.e. lines not eliminated on the basis of disease or size) for specific gravity.

If there is relatively little difference among progeny lines for the principle selection variable, size or value, the 3-P approach is at worst a good scheme for drawing a random sample with probability proportional to size of the individual trees within families. When this is the case, little difference in the number of individuals from the various families is expected in the subsample. Some trial runs with little differences among the family means for volume have shown this to be the case. Of course, the greater the differences among family means for the principle variables, the more biased the subsample becomes towards the larger, more valuable families. If desired, additional bias toward the larger, more valuable families can be obtained by assuring a specific number of "sure to be measured" trees. To do this, simply make K_A smaller than K which gives the trees in the range from K_A to K a probability of 1 of being sampled. Either of the 3-P systems outlined should reduce the quantification work associated with second generation selection to only a fraction of that required for total enumeration. More important, it is placing the subsample where it will do the most good--on the families containing the larger, more valuable trees.

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SESSION II

SEED ORCHARD MANAGEMENT, PROBLEMS AND PROGRESS

MODERATOR: W. L. BEERS, JR.

OBSERVATIONS ON TWO-YEAR RESULTS OF THE
SEED ORCHARD SURVEY (S.O.S.)

Earl W. Belcher, Jr. and Robert G. Hitt 1/

The yield and quality of seed from southern seed orchards were poor in 1969 and 1970. These poor results attracted the interest and promoted discussions among researchers and orchard managers. View-points expressed were that these results could have been due to environmental factors, cone and seed processing techniques or wide variations in measurement procedures. Diverse methods of data collection and procedures of handling between orchards as well as the wide geographic distribution of orchards made valid comparisons difficult. It seemed necessary to devise a standardized sampling method in order to establish base means for comparisons and to identify possible universal orchard problems.

With this in mind, the Southern Forest Tree Improvement Committee appointed an ad hoc committee on seed orchard seed yield and quality. The ad hoc committee then proposed a survey of southern seed orchards to identify problems, to indicate research needs, and to indicate immediate applicable orchard management procedures to improve seed quality and yield. The survey began in the fall of 1971 as a three-year cooperative project between interested orchard owners and the U. S. Forest Service. The results presented here are some highlights from the first two years of operation of this project.

METHODS AND MATERIALS

Each participating orchard manager selected 2 ramets from each of a minimum of 5 clones to represent the orchard. The following data was recorded: The total number of non-insect damaged cones (by visual inspection) from each ramet, the number of bushels this represented (to the nearest 1/4 bushel), the number of insect damaged cones, age of ramet, and insect control measures applied. The cone collector randomly selected 10 non-insect damaged cones from each ramet and sent them with the above information to the Eastern Tree Seed Laboratory at Macon, Georgia. (A series of slides was used with the talk).

At the laboratory, the cones of each ramet were placed in individual drying boxes and subjected to 24 hours drying at 110°F in a 100 bushel capacity kiln. After drying, the seeds were extracted by hand, dewinged, counted, x-rayed and germinated. Only 100 seed per lot were x-rayed and these seed were always the first replicate in the 400 seed

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germination test. The seeds were germinated on cellulose paper in plastic boxes at 72°F with 16 hours of light for 28 days. Loblolly seed were prechilled on the medium for 30 days at 34°F before germination. Counts were made every seven days. A seed was considered germinated when the seed coat was lifted from the medium.

From the data submitted and laboratory analysis, the following information was determined and reported to the cooperator: Number of cones per bushel, total number of seed extracted per 10 cones, number of seed per cone, percentage of insect damaged cones collected, x-ray analysis of 100 seed sample, full seed germination, number of lots showing seed mold in test, and notes on observations about cone arrival and germination test. The number of seed/cone was determined by dividing the total number of seed extracted by the number of open cones plus one-half the number of half opened cones. For this report, additional information was computed to provide a comparison of yield and quality between orchards. In using this data, orchard managers must recognize that there are age and size differences between orchards as well as differences in management. This new item is the number of viable seed per tree extracted from cones which were visually considered to be free of insect damage.

Our discussion today will include some overall summaries and observations as well as sectional summaries. The orchards were categorized into eastern, central and western groups. The eastern includes the Carolinas and Virginia; central encompasses Georgia, Florida, Alabama and Tennessee; while the western includes Texas, Louisiana and Mississippi. The slash (Pinus elliotii) data is from 2 orchards in the east, 24 in the central and 3 in the west, while loblolly (Pinus taeda) is from 12 in the east, 7 in the central and 6 in the west.

RESULTS AND DISCUSSION

The slash pine results are the average of 29 orchards in eight states from Virginia to Texas, while the loblolly averages are from 25 orchards in 9 states. Cones from a total of 528 slash ramets were received the first year but only from 456 the second. A total of 674 loblolly were received the first year and only 568 the second year. While most of the ramets not sampled the second year were reported to us as not producing cones, we based our summary on the assumption that all of the unsampled trees had no cone production.

Let's look at the results of several scored factors including cone opening at the Lab, cone and seed yield, insect damaged cones and x-ray analysis of seed, germination, insect control and finally, the number of thousand viable seed per tree.

Cone Opening

Cone opening, in general for both species the first year was good with the exception of the first cones received. They were immature. Cones from the first ten slash orchards received in 1972 arrived at the Lab between September 15 and 22. Although they were not necessarily from the same orchards, the cones arrived in 1972 during the same time period as the cones from the first 10 orchards for 1971; however, slash pine cone opening in 1972 was less than 50% in all cases. The problem seemed to be caused by a combination of factors. The cones of many samples were definitely immature; some, when finally opened, were found to contain nothing but immature seed or just wings. Some cones had insect damage of a magnitude which prevented the cone from opening. No such problem was noted with loblolly pine which had better than 8 out of 10 cones opening both years. Although only non-insect damaged cones were to be submitted, 3 percent of the cones from first year ramets and 5 percent of the cones from second year ramets submitted had visual insect damage.

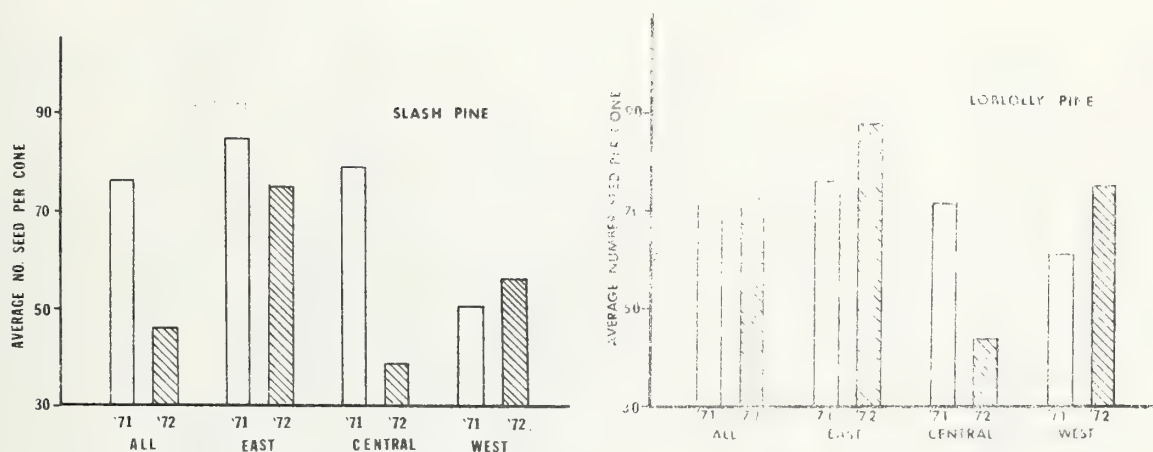


Figure 1. A (Slash pine) and B (Loblolly pine). Mean seed per cone extracted at the Eastern Tree Seed Laboratory. Data given for all orchard collections and by regions to be compared with the mean potential of 163 for slash and 150 for loblolly.

Let's look at a few bar graphs. In Figure 1 the average number of seed/per cone is shown. Note overall average from all orchards on left - note year differences. Note general decrease from East to West for slash pine. For loblolly the differences were not as great.

Figure 2A shows the --
Average number of cones/tree - slash pine showed some year differences and an East to West decline.

Figure 2B shows the --
Average number of cones/tree for loblolly pine.

Note that the Central Area was greatest in '71 but '72 showed the East to West decline.

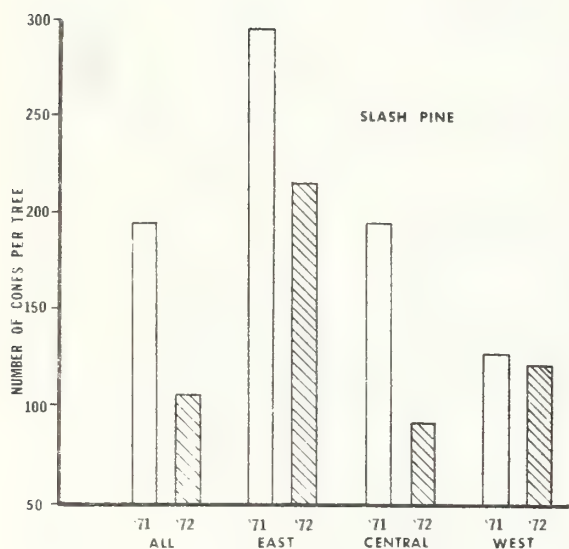


Figure 2A. Cone production of selected slash pine ramets as reported by the orchard managers.

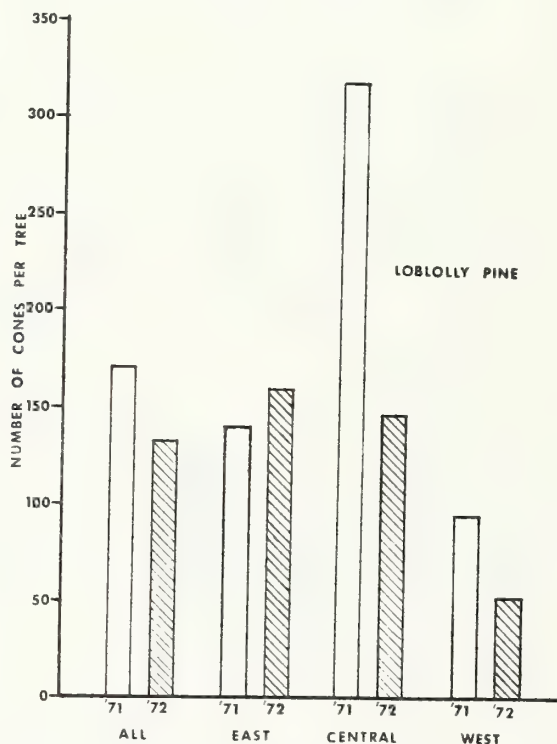


Figure 2B. Cone production of selected loblolly pine ramets as reported by the orchard managers.

Let's look at some graphs of the effects of insect control measures on seed and cone production.

In Figure 3A --
For slash pine, note control vs treated effect the overall and the yearly differences.

Note difference in seed yield for control and treated and the difference between the 2 years.

Figure 3B shows the results for loblolly pine.

Cone and seed yield both were improved by treatment both years.

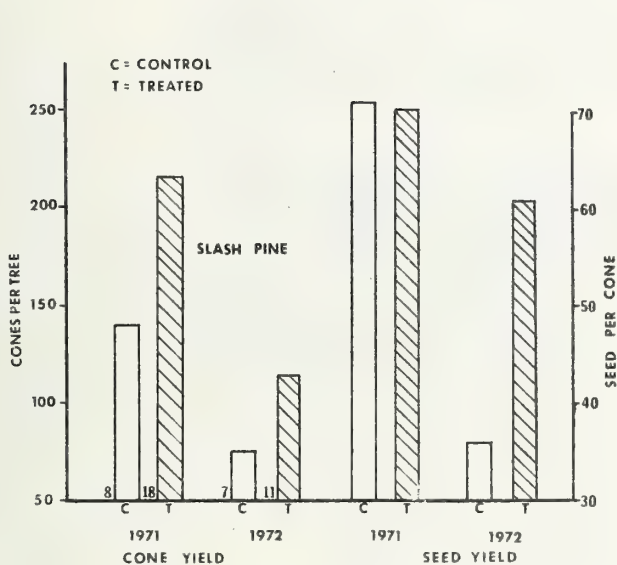


Figure 3A. Comparison of slash pine cone and seed yield from treated and non-treated trees for two years. Numbers at left base of bars indicate the number of ramets included in averages.

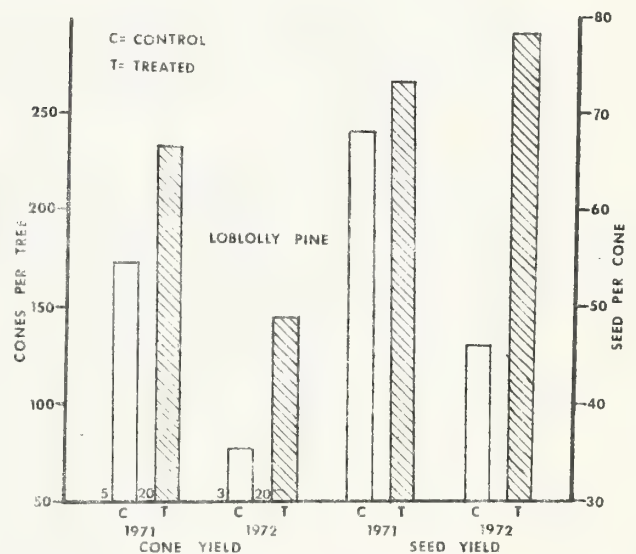


Figure 3B. Comparison of loblolly pine trees subjected to insect control measures with non-treated trees on cone and seed yield for each year of the survey. Numbers at left base of bars indicate the numbers of ramets included in averages.

Viable Seed Per Tree

Thus far, we have discussed observations and determinations from field and laboratory data. None of these measurements are adequate for comparing orchards though, since they all have built in bias. Comparisons of production using cones per bushel do not reflect the number of viable seed per bushel. Also, comparisons based on seed weight (seed per pound) do not allow for differing percentages of empty seed. Seed size also varies with source thus biasing any comparisons between the eastern and western sources.

A new measurement was developed which will reduce the biases previously mentioned; however, it does not permit accurate comparisons of orchard production. There are still the factors of ramet age, size and actual orchard management which will affect orchard seed production. The new measurement is the number of thousand (M) viable seed per tree. The formula for computing it is:

$$\text{M viable seed/tree} = \frac{\text{calculated non-insect cones seed/cone collected (actual germination)}}{(\text{No. of ramets involved in calculations (1000)})}$$

Although these computations should allow for better comparisons, one must remember that these figures only reflect the mean of those clones submitted and have the constraints just mentioned. (Size, age and orchard management).

Seed yield on this basis was 3 times greater for slash pine in 1971 compared to 1972 while only a slight difference was noted in loblolly (Fig. 4A & 4B). This measure followed the same trends as noted in cones per tree (Fig. 1A & 1B). The seed production in 1971 was about the same for both species.

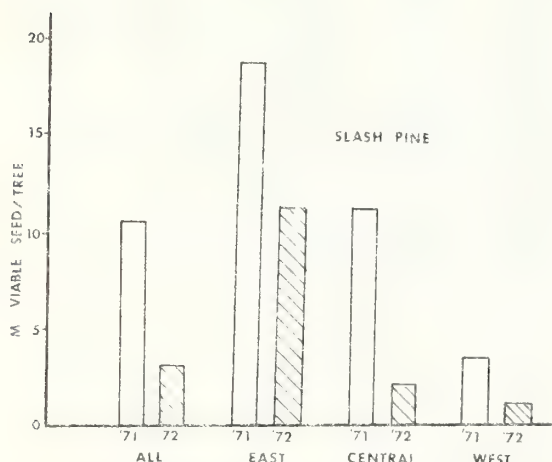


Figure 4A. Thousand viable seed per tree produced by slash pine seed orchard trees sampled in the seed orchard survey.

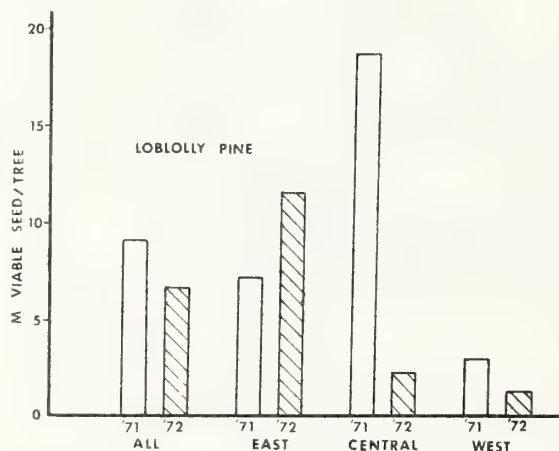


Figure 4B. Thousand viable seed per tree produced by loblolly pine seed orchard trees sampled in the seed orchard survey.

If we consider potential seed production/cone for slash to be 160-170 seed/cone and for loblolly to be 150+ seed/cone, then one can see what potential seed production has been lost due to other factors including poor pollination and selfing. See Figures 5A and 5B.

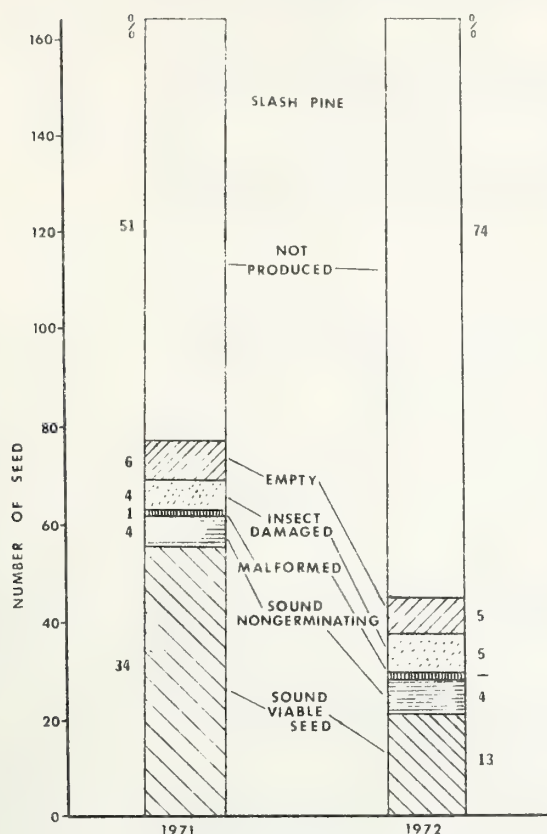


Figure 5A. Summary of slash pine seed production per cone. Data based on laboratory findings and assumption that each cone has a potential to produce 163 see

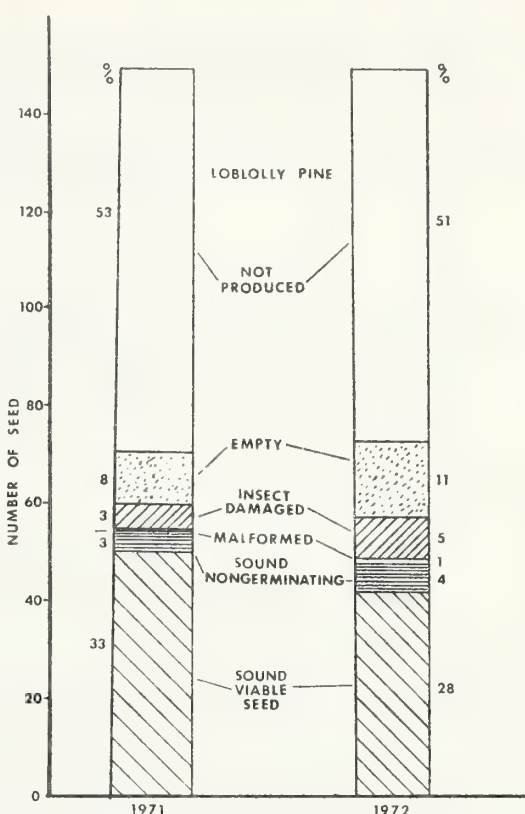


Figure 5B. Summary of loblolly pine seed production per cone. Data based on laboratory findings and assumption that each cone has a potential to produce 150 seed.

Let's consider now a summary of findings on the seed which was extracted:

- A reduction was observed in cones/tree and seed/cone for slash pine in 1972, while the number of cones/bushel held the same. This indicates that there was no influence on cone size caused by a drastic change in the number of cones produced per tree or in the amount of seed they contained.
- No difference was noted in loblolly cone seed yield for the 2 years. An East to West reduction was noted for seed and cone yields.
- X-ray analysis of the seed indicated that the largest percent of seed was in the empty category followed by identifiable insect damaged seed.
- Actual germination percent was low for both species but full seed germination percent was good. Germination percent was increased further by removing all insect damaged seed. This emphasizes the importance of proper cleaning of seed orchard material.
- Comparison of seed from trees receiving insect control measures to those receiving no treatment showed:
 - (1) Insect control increased cone yield.
 - (2) Insect control increased seed yield in 1972 but had a negligible influence in 1971.
- Selfing, known to occur in seed orchards, can be a contributor to poor seed set. S.O.S. data cannot detect this factor.
- A possible measure of comparison between species is thousand (M) viable seed/tree. This measure followed the same trends as cones/tree.

Recommendations to date are:

- (1) Orchard managers should use an insect control program and they should use it every year to minimize insect damage.
- (2) Proper cone and seed handling insures maximized seed viability.
- (3) Harvest only fully matured cones. Screen them carefully for insect and disease damage. For survey purposes, send only insect free cones to the Lab.

Good seed gives good results, poor seed poorer results and junk is junk!

CONTINUED RELIANCE ON WIND-POLLINATED SOUTHERN PINE
SEED ORCHARDS - IS IT REASONABLE?

R.A. Woessner and E.C. Franklin^{1/}

Abstract.--During the past 15 years a tremendous amount of individual and organizational energy has been devoted to successfully establishing southern pine seed orchards. Many orchard management techniques have been perfected. A review of the current status of the orchards indicates that a system such as mass dusting of orchard ramets with pollen could serve several useful purposes. Whether supplemental pollination will prove to be economical remains to be seen. However, the potential gains to be made in this direction and the reduced gains if the wind-pollinated orchards performed at their worst certainly indicate that more thought and research effort should be given to this particular aspect of seed orchard management.

Additional keywords: Supplemental pollination, mass-artificial pollination, Pinus taeda, Pinus elliottii, Pinus echinata.

The successful operation of southern pine seed orchards is based upon a number of biological principles and assumptions. To the extent that these are not fully satisfied, or are only partially satisfied, the orchards will not produce seed of the most desired genetic constitution. With all factors considered relating research results and observed performance of the orchards to date, it appears that a supplemental pollination system is needed, such as mass dusting of orchard ramets, as described by Wakeley et al. (1966) whereby the pollination process in the seed orchards is controlled to a greater degree than with wind-pollination.

WHAT ARE THE PROBLEMS WITH THE WIND-POLLINATED ORCHARD

To have maximum efficiency, the "ideal" wind-pollinated, general combining-ability seed orchard relies on the following: (1) the orchard ramets of each select tree will be more or less completely isolated from surrounding unselected trees; (2) ramets will be equally productive of male and female flowers; (3) ramet pollen flight and female flower receptivity will coincide; (4) crosses among clones will be equally compatible; (5) natural self-fertilization will occur at insignificant rates. It appears that not all of the above conditions are being completely realized in practice in a large number of orchards.

Contamination by Foreign Pollen

When wind-pollinated species are established in seed orchards, dilution zones are usually established to prevent contamination from outside sources of pollen. This is understandable because expected genetic gain from seed produced on orchard ramets pollinated by unselected trees is one half that expected if both parents were in the orchard. Seed by contaminating pollen is genetically equivalent to open-pollinated seed from the selected ortets in the woods.

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The frequency of such seed is dependent on the availability of foreign pollen. This is especially important in the south because of the difficulty in establishing a seed orchard that is suitably isolated from the vast acreages of natural and artificial pine stands.

Considerable research in this country and in Europe has been devoted to the study of pollen dispersion; for example, Wright (1953) has shown that the amount of contamination for any given ramet depends on factors such as the size and age of the orchard, the location of the ramet within the orchard and the size and type of dilution zone. Dilution zones with a minimum of 500 feet were recommended for southern pines based on data that indicated only 5 percent of pollen from a particular tree will travel 500 feet or more (McElwee 1960, Wang et al. 1960). In Europe, Andersson (1955) estimated as much as 30 percent contamination from studies with Norway spruce (Picea abies L.) and Scots pine (Pinus sylvestris L.) at dilution zone distances up to sixteen times greater than the minimum recommended for southern pines. Wang et al. (1960) quoted the minimum width of 500 feet to be satisfactory as follows: "The percentage of extraneous pollen, therefore, would be negligible when the trees in the seed orchard begin to produce pollen in quantity as they reach seed production age. Turbulence and unusual weather, however, can make an isolation strip adequate one year and inadequate the next." McElwee (1960) states quite the same: "Distances which prove to be effective barriers in one year will be insufficient in another." A publication by Lanner (1966), mainly a synthesis of research by others, points out that weather conditions which favor pollen shed promote the formation of strong thermal shells (the normal mechanism by which warm or moistened air rises) and suggests that these shells may provide for uplift and transfer of pollen long distances. He feels that the practical isolation of open-pollinated seed orchards seems even riskier than presently thought and they will be subject to erratic and perhaps unpredictable meteorological forces. The interesting point here is that a weather condition which is conducive to maximum pollen shed in the orchard (warm dry air) could also increase the amount of pollen reaching the orchard from outside, unselected sources.

Presently, there are no direct estimates of the amount of contamination in large commercial orchards. Squillace (1967) in a 5-acre orchard did demonstrate for slash pine (Pinus elliotii Engelm.) that if the orchard produced no pollen at all, pollen from outside the orchard was of sufficient abundance to produce normal yields of 50 full seeds per cone.

Equal Productivity

Sizeable variability among clones in production of both female and male flowers has long been evident to anyone working in a seed orchard. Kellison (1971) indicates that the reproductive behavior of second-generation orchard trees is especially important because of the fact that 80 percent of the seed obtained from the first-generation orchards is produced by only 20 percent of the clones. Thus, some of the most productive orchard genotypes are produced in limited numbers because of low fecundity. Kellison (1971) and van Buijtenen (1971) indicate by their discussion that differences also exist among clones in pollen production. Bergman (1968) subjectively rated 15 loblolly clones for their pollen producing ability on a scale from 0 to 5. The poorest clone scored .2 and the best 5.0. He concluded from the data on female and male flowering intensity that 50 percent of the progeny from one orchard would come from the two heaviest cone-producing clones. He also found that clones vary in the number of seed per cone (52 to 122 seeds per cone) and the percentage of unfilled

seed. The percentage of unfilled seed varied from 53 to 8 percent. Clones can have low filled seed yields because of natural selfing or because they are out of phase with the other clones in the orchard. Supplemental pollination could alleviate these problems and thus bring about a more equal production from the orchard clones. The age of the orchard and ramet spacing are also recognized factors affecting the percentage of filled seed. In the early years, pollen is quite scarce. Supplemental pollination could alleviate the problem of a pollen shortage in young newly established orchards. Likewise, because of the scarcity of pollen in the formative years of the seed orchard, four times as many grafts are planted than are ultimately desired (Kellison 1971). With supplemental pollination, perhaps fewer grafts would have to be established initially.

Floral Phenology

There is considerable older documented evidence of differences in male flower anthesis and female receptivity (McElwee 1960, Goddard 1964, Jurriaanse 1964, Dorman and Barber 1956). Recently, a report from the Western Gulf Forest Tree Improvement Program indicates that two slash pine orchards flowered well in the spring of 1972, but pollen was not synchronized with female flower receptivity so seed yields were projected to be low in 1973.^{1/}

Wasser (1967) did a floral phenological study of seed orchard loblolly pine (Pinus taeda L.) and shortleaf pine (Pinus echinata Mill.). The female flowers of the clones could differ in maximum receptivity by five days. Pollen of some clones was shed before orchard maximum female receptivity. In other clones, pollen shed lagged behind orchard maximum female receptivity.

A study with shortleaf pine indicated repeatability in fruitfulness and timing of pollen shed. Schmidting (1971) found that pollen-bearing trees could be predicted from past performance with a fair degree of accuracy. Also there was fairly good agreement in individual trees as to time of shedding from 1969 to 1970 ($r = .827$).

In order to circumvent the phenology problem, Barber (1964) suggested that adequate numbers of phenologically matched individuals be included within the orchard to yield maximum cross- and minimum self-fertilization. This is an imposing task and it is not sound to use genetic selection to circumvent a problem which might better be handled in another manner. To satisfy the flowering criteria we might be lowering the selection differential for the economically desirable characteristics.

Equal Compatibility among Clones

Incompatibilities among clones are quickly evident to anyone attempting to complete a specific number of crosses for a progeny testing scheme. Seed is obtained in abundance for some crosses whereas other combinations are partially or completely incompatible. Partial incompatibility is indicated by the results of Snyder and Squillace (1966); they report averages of 29 seeds per cone from multi-pollen versus 18 seeds per cone when a single male was used. These values are based on results from a great number of crosses.

^{1/} Texas Forest Service. 1972. 20th Progress Report of the Cooperative Forest Tree Improvement Program. Circular 213.

Self-Fertilization

The detrimental effects of self-fertilization are readily recognized in the southern pines. Studies by Kraus and Squillace (1964) with slash pine and Franklin (1971a) with loblolly pine attest to the high rates of selfing in these two species. Studies of selfing in southern pines have consistently shown drastic reduction in yields of filled seed and moderate to severe reductions in germinability of filled seed and in subsequent height growth of seedlings (Franklin 1969, 1970). High rates of selfing within seed orchards may be one major factor in reducing yields. It has been observed that seed yields in many orchards start out at satisfactory levels for the age of the orchard but then show a relative decrease with increasing orchard age (Franklin 1971b). This result is found because in a young tree the female conelets are borne near the top and the male catkins near the bottom of the crown and selfing is minimal. But the typical result of crown development in orchard trees is that the midcrown becomes an area of intimate association of conelets and catkins. This leads to a tremendous increase in self-pollination in the lower and midcrown areas.

The result of the last four mentioned factors (i.e., equal productivity, phenology, compatibility and selfing) is that we do not actually have equal numbers of progeny from each clone contributing to orchard production. Thus, instead of the orchard being composed of random cross-breeding clones, it consists of a series of specific crosses between the clones in which compatibility, receptivity and pollen anthesis happen to coincide. This specificity of crossing is determined by the individual genetic constitution of the clones, the particular weather conditions prevailing in any given year, and the location of the ramets of various clones within the orchard. Within seed orchards specific limited combinations are being produced, but not on the basis of characteristics of importance to the forest manager, such as increased growth or disease resistance. Combinations are determined purely on the basis of compatibility, receptivity of conelets and availability of pollen.

WHAT IS AN ADEQUATE GENETIC BASE

The superior tree concept along with the rest of forestry is being criticized by the environmentalist faction. The environmentalists question the use of a few genotypes to regenerate large acreages. Nelson (1971) in the 11th SFTIC Keynote address states that we must really work at keeping a broad genetic base and questions whether the base of first-generation-orchards should have been broader. The question is not easily answered. However, it appears that in some cases a lot of acreage could be regenerated with a limited number of genotypes. Assume a 20 clone orchard of 40 acres in size that will have a seed producing life of 25 years. Further assume a regeneration rate of 300 acres per acre year of orchard for the 25 years or a total of 300,000 acres regenerated. Also assume that 80 percent of the seed will come from 20 percent or four of the clones. Over the 25 years, 240,000 acres would be regenerated with 4 maternal parents. Supplemental pollination could help broaden this genetic base by assuring that different male parents were involved. Males chosen for supplemental pollination could be chosen on the basis of superiority so that the overall percentage gain of the orchard would be increased. A striking example of the effect that different male parents can have on progeny rust infection when crossed to a common female is presented by Woessner (1965). Five

loblolly males were crossed to a common female (Table 1). The female parent, 11-2, was shown by an open-pollinated test to be 22 percent above average in rust susceptibility whereas the five males averaged 9 percent below their plantations. The full-sib crosses of 11-2 with the five males averaged 37 percent infection while the range was from 11 to 59 percent.

Table 1.--Comparison of percent infection of southern fusiform rust on open- and control-pollinated families; tree 11-2 was the female parent in all the control crosses.

	Open-pollinated		Control-pollinated	
	% infected	Plantation mean	% infected	Plantation mean
11-41	14	34	11	37
11-9	26	34	21	"
11-20	13	19	37	"
7-34	22	27	55	"
11-18	16	19	59	"
11-2	41	19		

THE EFFECTS OF THE ENVIRONMENT ON FLOWER PRODUCTION

Weather conditions can influence orchard performance in ways other than pollen dispersion (Lamb *et al.* 1973). These need not be as drastic as hail or freezing weather which affect both the female and male flowers. Cool, wet weather in the spring can result in the female flowers continuing to develop while the male flowers are retarded. Even if the catkins have reached maturity, rainy, damp weather retards shedding. Climatic and site conditions also influence the male and female flowers differently. On two matched orchards in different areas, Jurriaanse (1966) found that the one getting the lowest rainfall produced the greatest number of female flowers per ramet. Timing of moisture is also important in female flower production (Lamb *et al.* 1973), Dewers and Moehring 1970). Conversely, a positive influence of moisture on pollen production relative to cone production was indicated by the work of Florence and McWilliam (1956). They showed that wild stands on better, more moist sites produced 1.3 times as many cones but 4.2 times as much pollen as the dry site.

Management practices currently used in the majority of orchards appear to be aimed mainly at increasing the overall yield of cones, not assuring that maximum pollination takes place. This situation could arise because of an interaction between irrigation, fertilization and male and female flower production. Studies by van Buijtenen (1965) indicate that mineral fertilization increases the number of female flowers, decreases the number of male flowers, but overall cone production is increased. Bengston (1965) states that irrigation had a significant depressing effect on female flower production, but promoted pollen production. In a seed orchard study combining irrigation and mineral fertilization, Gregory (1968) found that irrigation increases male flower production relatively more than fertilizer alone, while irrigation and fertilization together gave the greatest increase over the control. Fertilizer gave a

greater increase of female flowers than irrigation, but both together produced many more cones than the control. But, cone production is only part of the story; also important is the number of germinable sound seed per cone. Sound seed per cone is known to double in years of pollen abundance. (Florence and McWilliam 1956). Van Buijtenen's data (1965) shows that the control had greater pollen production but 10 percent less sound seed than the fertilized plots in a year which had a normal spring. The next year the control again had the greatest pollen production but due to a freeze which damaged the pollen, the control exceeded the fertilized plots in percentage of sound seed by 38 percent, although having only 49 percent as many total seed. Thus, although fertilizer increased the number of cones and increased yield generally, it appears to have decreased pollen production to the point that it became critical in a poor year. A similar situation was found by Gregory (1968) in that the control and irrigated only plots have a higher percentage of full seed than the fertilized and irrigation plus fertilized plots. There were no data concerning pollen production for this particular seed crop.

Strictly from a viewpoint of orchard management, even if a near randomly breeding, well-isolated orchard composed of self-sterile clones existed, relying wholly on wind-pollination must be considered a weak link in the efficient production of seed. For maximum efficiency, orchards must produce crops annually in spite of the weather. The effects of weather could be overcome considerably if mass artificial pollination is used. It certainly cannot make up for losses in conelets due to hail or freezing weather, but it could assure that the cones that matured would have larger numbers of filled seed per cone. The amount of money spent on orchard maintenance and protection is dependent on the size of the orchard, not on the yield for any given year. It costs just the same to protect, irrigate, and fertilize a tree with 20 cones as the same tree having 120 cones. The same is true whether the cones have many or few sound seed.

IS SUPPLEMENTAL POLLINATION FEASIBLE

Gains from applied breeding programs are not absolute but must be considered in terms of cost per unit of improvement. Up to that point in time when improved seed is available for all the needs of all planting programs, any cultural practice which would increase the total annual seed yields from an orchard should be considered feasible if the cost per pound did not exceed the point at which it was more profitable to plant nursery run seedlings.

Results in certain South African orchards have overwhelmingly proven the ability of artificial hand pollination to increase seed yields. It was conclusively demonstrated that hand pollination more than doubled the yield of filled seeds compared to orchard open-pollination even with abundant pollen production in the orchard (Denison 1971).

Recent results indicate that the first pollen to reach the female flower has the highest probability of effecting fertilization (Franklin, in press). Therefore, if weather conditions cause the conelets to be receptive before pollen flight from the same tree, either orchard pollen or foreign pollen would have the first opportunity for pollination. If pollen flight and maximum receptivity coincided, much self-pollination and eventual self-fertilization would probably take place because of the high density of self-pollen in the area of receptive, previously unpollinated conelets. If mass-artificial pol-

ination were done as soon as or slightly before conelets reached maximum receptivity, the frequency of self-fertilization as well as fertilization resulting from pollination by non-orchard pollen could be drastically reduced. This would be due to the result of the mechanism of the pollination droplet described by Doyle and O'Leary (1935). The pollen is captured in a droplet of fluid which exudes from the nucellar tissue. When several pollen grains have been captured, the droplet will not exude again. When self and cross pollen grains are captured within the same droplet, all evidence indicated that the self-pollen suffers no disadvantage in accomplishing fertilization (Franklin 1970). But the embryo resulting from self-fertilization would usually be at a disadvantage, especially if it had to compete with an embryo resulting from cross-fertilization (Fowler 1964). Thus, even a mixture of artificially applied cross pollen with native self-pollen would be preferable to self-pollen alone.

Producing more seed is only part of the answer. In looking toward the future, we must consider current trends in forest management and see how mass artificial pollination fits with them. The argument has been presented in the past (McElwee 1960) that we do not need all superior seed because we always harvest fewer trees than we plant. This argument is much less relevant now than originally proposed. Such an argument is reasonable under forest management with a close original spacing and one or two low selective thinnings to remove the poorer trees. Current management practice is dictating short rotations, wider spacing, non-selective row thinnings and uniform tree sizes for mechanical harvesting.

Management is not only demanding uniformity in seed quality, but also seed of a specialized nature--seed that will produce trees suited for special purposes and for special sites. Even now one sees the demand for trees with specific wood properties, high resistance to Cronartium, better response to fertilizer, or seed with specific germination properties for direct seeding. What happens when the results of the progeny tests indicate that certain parental combinations are growing faster, and straighter, and are more disease resistant but one of the parents is either a poor cone or pollen producer or is out of phase with the rest of the orchard? Several alternatives are available such as using two-clone orchards, controlled-pollination, mass dusting, or even new selections. The ultimate solution might be two-clone orchards supplemented with mass-artificial pollination. But how are we to supply these needs as quickly as possible? Are the management personnel going to be willing to wait six or seven years for us to re-establish new orchards?

In the meantime, however, in the present orchards, we can increase the percentage of desirable offspring simply by mass dusting with known good combiners. Only a portion of an orchard system might be managed for production of pollen, the remainder managed for production of seed. When rogued, the clones left in the seed production orchard would be judged on general performance of progeny and cone productivity. The former should be given the most weight, but the seed orchard should be managed to give maximum cone production at the expense of pollen production. In order to avoid outside contamination the orchard could be put out of phase with the surrounding area by irrigation^{1/}

^{1/}Anon. 1966. Tenth Annual Report N.C. State-Industry Cooperative Tree Improvement Program.

(Silen and Keane 1969). Pollen for mass dusting could come from a pollen orchard managed specifically for pollen production, the individuals here judged on the basis of pollen productivity and general performance of progeny. Such pollen orchards might be located several hundred miles south of the cone producing orchard to assure that the pollen would be available before the conelets were receptive.

SUMMARY

A review of the current status of pine seed orchards indicates that (1) some present day orchards are not randomly breeding and clones differ in productivity of pollen, cones, and seed; this can result in a narrowed genetic base, (2) lack of adequate amounts of pollen can result in high proportions of contaminate pollen or too little pollen for maximum seed set, while large amounts of pollen may cause excessive selfing, (3) weather conditions may drastically affect yields and the seed quality, and (4) current orchard management practices could be altered to favor either male or female flower production as needed.

To offset the above adverse conditions in the seed orchards, mass dusting of ramets with pollen as described by Wakeley, *et al.* (1966) and Franklin (1971b) could have the following beneficial effects: (1) higher, earlier and more consistent seed yields, (2) less selfing, (3) a greater percent improvement from the established orchards by using highly superior clones as male parents, (4) the genetic base of an already established orchard could be broadened.

Whether supplemental pollination proves economical remains to be seen. However, the potential gains to be made in this direction and the reduced gains if the wind-pollinated orchards performed at their worst certainly indicate that more thought and research effort must be given to this particular aspect of seed orchard management.

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TREE IMPROVEMENT IN INTERNATIONAL PAPER COMPANY'S DELTA REGION

Howard Johnson 1/

Abstract.--The McNair Seed Orchard, its insect control, fusiform rust problems, cone picking, some production figures, and the results of its first 5-year progeny test, which shows an average of 26.84% volume superiority, are discussed. During the 1973-74 planting season approximately 100 each of half-sib seedling families of superior sweetgum and sycamore phenotypes will be planted in two locations as progeny tests. Later, parts of one test will be made into a seedling seed orchard.

Additional Keywords: Pinus taeda, Liquidambar styraciflua, Platanus occidentalis, Cronartium fusiforme.

DELTA REGION

The Southern Kraft Division of International Paper Company is divided into five Woodlands Regions. The Delta Region covers roughly the Northwest 80% of Mississippi and approximately the Southeast 75% of Louisiana.

MCNAIR ORCHARD

In 1960 we started the 49-acre McNair loblolly pine (Pinus taeda L.) seed orchard, which is located 35 miles northeast of Natchez, Miss. This orchard has five types of soil which are loessal. Rainfall over the past 13 years has averaged 54" with a high of 79" and a low of 39". We do not always get the moisture we want when we need it the most. The origins of our clones are: 1 from Texas, 7 from Arkansas, 14 from Louisiana, and 9 from Mississippi. The average age of our ramets is nine years.

Insect Control

In controlling insects we use a Super Hurricane mist blower and two 100-gallon fiber glass tanks, mounted on a Ford 5000 diesel tractor. This tractor is operated in 3rd gear, low range, at 1900 rpm, or at 3.26 mph, causing the power takeoff to turn the mist blower at the recommended 540 rpm. We make three trips a day, putting out 200 gallons of 1.33% Guthion each time, quitting about 11:00 a.m., because of the unbearable heat. It takes three days to spray the entire orchard. We spray down one side of a row and come back on the other side of the same row to insure complete coverage. Generally we start spraying on or about the 15th of the following months: April, May, June, July, and as soon as cone picking is over. Since the operator of the mist blower has to be bundled up in hot, protective rubber clothing, we use the White Cap system, which filters and cools the operator's air and prevents condensed moisture from collecting on the inside of his mask. A local medical doctor makes cholinesterase tests twice each year.

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Fusiform Rust

We have had an annoying fusiform rust (Cronartium fusiforme H. & H.) problem at McNair during the last four years. We planted the 400-foot "pollen dilution" strips with sweetgum and sycamore and followed with clean cultivation. The oak host immediately adjacent to the orchard has consequently been eliminated. The sweetgum and sycamore will, when they have attained sufficient height, form a screen that should intercept spores produced by the fungus on surrounding oaks.

In order to better cope with the rust infections presently existing in the orchard, we have classified all galls into three categories: (1) gall on the main stem, (2) limb gall within two feet of the stem, (3) and limb gall farther than two feet from the stem. We attempt to excise the galls on the stem and closely watch the number two category so that we can cut off the branch when the gall begins to endanger the stem. The galls in the number three category are ignored. Table 1 below summarizes the number of galls of each type we have removed to date.

Table 1.--Number of galls of each type removed to date per year

<u>Year</u>	<u>No. 1 Gall</u>	<u>No. 2 Gall</u>
1970	103	37
1971	53	85
1972	74	122
1973	56	85

Cone Picking

During cone picking, we cover the orchard three times, because, thank the Lord, not all of our clones' cones mature at the same time. Usually, the first phase is ready on September 17, and the entire operation is completed in 4 to 5½ weeks, depending on the size of the crop. We have gone through an array of cone picking methods: (1) by walking, (2) from step ladders, (3) from pickup cabs, (4) from low, home-made platforms, (5) from high platforms, (6) from 24' and 27' Selma Man Lifts that rent for \$500-\$525 per month, and (7) from the Elliot High Reach with either the 45' or 50' platforms. Its platform is 70" x 40", big enough for two people to work comfortably all the time. This machine, mounted on a truck, rents for \$1,150 per month. We can pick two adjacent ramets from one setting. The third man in the crew drives the truck, sets the outriggers, and pitches most of the picked cones to the base of the ramet. A follow-up crew picks up the cones, cleans them of trash and puts one bushel into each sack. This crew later stores the sacks outside on cone racks that prevent them from touching the ground.

Production Figures

Here is a chart of some of McNair's production figures.

See Table 2 on the following page.

Column 9 is a prediction I helped to make in 1965. This prediction is based on the premise that each 20-year-old ramet would produce one bushel of

Table 2.--McNair's production figures

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7	Column 8	Column 9
Year	% Ram- ets bearing 1 or more cones / year	No. of cones/ bushel	No. of bushels/ year	No. of lbs. of seed/ year	Lbs. of seed/ bushel	Eastern Tree Seed Lab. Figures		1965 Pre- dic- tion of Yearly lbs. of seed to be pro- duced
						No. of Seed/lb.	%Germ. 30 Day strat.	
Started in 1960			Total acres = 49					
1965	?			0 ³	-			1 ²
1966	27			7 ⁰	-			3 ⁵
1967	47	291	85	87 ⁰	1.02	15,780	83	11 ⁹
1968	52	278	208	283 ⁰	1.36	16,380	89	26 ⁴
1969	62	338	162	110 ⁰	0.68	18,360	73	49 ⁷
1970	66	374	187 ¹ / ₂	34 ⁰	0.18	-	-	84 ⁸
1971	80	321	892	1123 ⁰	1.26	17,350	93	137 ⁰
1972	60	307	168	142 ⁰	0.85	17,906	88	212 ⁵

cones, which would yield 0.85 pounds of seed, and that mortality would be 1% annually. Over the past five years our mortality rate has averaged 2.3% per year.

As the proof of the pudding is in the eating, so the proof of our tree improvement program is in our progeny testing. During the years of 1967, 1968, and 1969, we have outplanted four 10-pollen polymix progeny tests. The 5th year measurements of the first test, which represented ten families, showed an average height superiority of 9.87%, and an average volume superiority of 26.84%, ranging from a high of plus 59% to a low of minus 3% over nursery run checks.

HARDWOOD TREE IMPROVEMENT

Beginning in the summer of 1968 all of our field people began to look for superior sweetgum (Liquidambar styraciflua L.) and sycamore (Platanus occidentalis L.) phenotypes. In selecting these trees, six traits were used in

scoring. Table 3 below shows this scoring process.

Table 3.--Six traits used in scoring sweetgum and sycamore phenotypes

1. Straightness	0 - 5 points
2. Crown	0 - 5 "
3. Epicormic Branching	0 - 3 "
4. Pruning Ability	0 - 3 "
5. Branch Angle	0 - 2 "
6. Apical Dominance	0 - 3 "
Total	0 - 21 points

No trees with less than 10 points were accepted. Since it is usually impossible to get comparison trees with either of these two species, each tree was scored individually.

We now have half-sib seedling families from nearly 100 sweetgum and nearly 100 sycamore trees being grown in a company nursery. In order to get the seed for this many trees we had to select 104 sweetgum and 108 sycamore. (See Figure 1.) During the 1973-74 planting season, seedlings of each of these species will be outplanted in progeny tests on a bottomland hardwood site, located close to the Mississippi River, near Rodney, Miss., and on a loblolly pine site of 100-110 in the hills of Copiah County, Miss. Each family will be represented in a 5-tree row plot in each of five replications at 10' x 10' spacing. It is our plan to cultivate six or more times each year for at least two years. Starting with the fifth year, we will begin to rogue out to about 45 trees per acre, on the upland site only, at least two replications each of sweetgum and of sycamore. There, we will cut out everything but the best individual trees in the best families. After 5 to 10 years we should begin to get seed production. If necessary, we could still start grafted orchards of both species.

Hardwood Seed Orchard

We will end up with one seed orchard with at least 2.725 acres each of sweetgum and sycamore. When in full production, one acre of sweetgum orchard should produce enough seed to plant 2100 acres per year; and one acre of sycamore orchard should plant 372⁴ acres per year. This orchard acreage will more than satisfy all of the Delta Region's hardwood needs in the future.

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FIGURE NO. 1

DELTA REGION

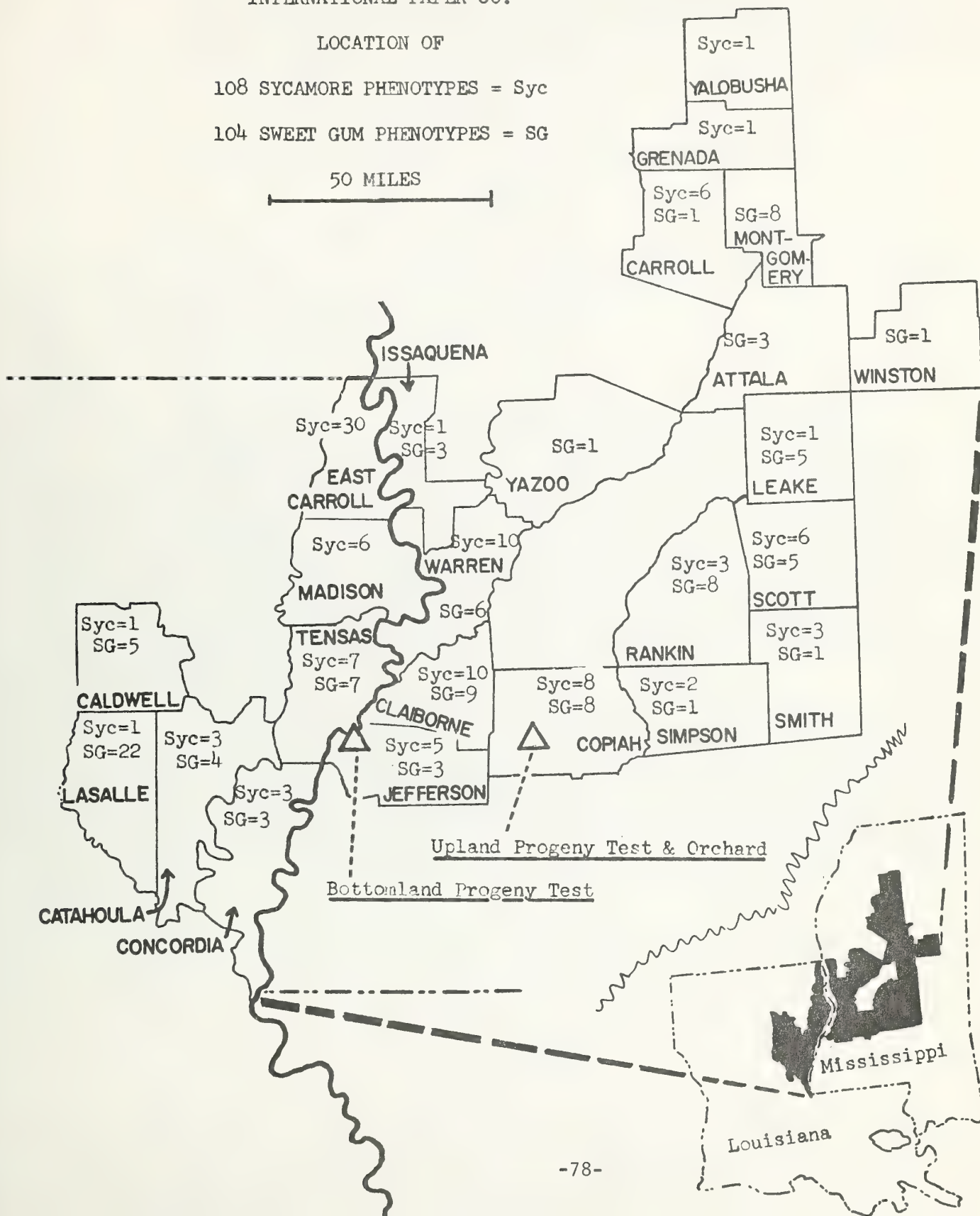
INTERNATIONAL PAPER CO.

LOCATION OF

108 SYCAMORE PHENOTYPES = Syc

104 SWEET GUM PHENOTYPES = SG

50 MILES



SURVEY OF GRAFT INCOMPATIBILITY IN LOBLOLLY PINE

Clark W. Lantz^{1/}

Abstract-- A survey of graft incompatibility in 31 clonal seed orchards of 18 organizations within the North Carolina State University Cooperative Tree Improvement indicated that 22 percent of the 770 loblolly pine clones grafted had significant numbers of incompatible ramets. Smaller samples from slash, Virginia, shortleaf, and pond pine orchards suggested similar incompatibility rates for these species.

No relationship was found between incompatibility and the geographic location of ortets or seed orchards.

INTRODUCTION

Graft incompatibility has been one of the most serious problems in the establishment and management of clonal seed orchards. In some southern pine seed orchards over 60 percent of the clones grafted have demonstrated some degree of incompatibility, ranging from the gradual loss of vigor of a few ramets in some clones, to the sudden death of over 90 percent of the ramets in others.

One of the most troublesome aspects of graft incompatibility is the great variation in the time when symptoms are expressed. In loblolly pine (*Pinus taeda*) seed orchards, as many as 90 percent of the ramets of some clones have died from incompatibility during the first year after grafting. Other clones have performed very well until 6 to 7 years after grafting, when quite suddenly, 95 percent of the ramets died. This type of delayed incompatibility is particularly serious in a clonal seed orchard as it occurs when competition from the established trees is too severe to allow replacement of individual ramets. Not only is there a loss of the potential seed production of the affected ramets, but also the genetic base of the orchard is lowered due to a reduction in the number of pollen sources and their uneven distribution throughout the orchard.

In any discussion of graft incompatibility, it is essential to distinguish between mortality during grafting and aftercare, and mortality due to true incompatibility, which is the result of stock-scion interactions subsequent to the formation of a graft union. The terms grafting survival and incompatibility, therefore have essentially the same meaning as "graftability" and "delayed graft failure" as used by Duffield and Wheat (1964). The following terminology will be used throughout this paper:

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Graft incompatibility - Stock-scion interactions occurring in successfully established grafts, which cause a decline in vigor of either stock, scion, or both. Mortality which occurs prior to the formation of a functional graft union is specifically excluded.

Incompatible clone - A clone in which sufficient mortality and/or decline in vigor has occurred following grafting to indicate that incompatibility is the causative agent, rather than environmental factors.

PROCEDURES

A questionnaire was distributed to all organizations within the North Carolina State University Cooperative Tree Improvement Program in order to estimate the geographic distribution, frequency, and severity of graft incompatibility within the seed orchards of members of the cooperative. Completed forms were received from 18 organizations, representing 46 seed orchards containing 1,127 grafted clones of 5 pine species.

The survey data were summarized by species, state, and province, to indicate the number of incompatible clones in these categories (Table 1). The previously-mentioned definition of incompatibility was used as the criterion of the status of a individual clone. The majority of the clones classified as incompatible were those in which greater than 10 percent of the ramets exhibited definite symptoms of incompatibility. For purposes of comparison, data were also included for slash (P. elliotii), Virginia (P. Virginiana), shortleaf (P. echinata), and pond pine (P. serotina) orchards. (Table 2)

SURVEY RESULTS AND DISCUSSION

Incompatibility Rates

Of the total of 770 loblolly clones represented in the survey, 168 or 22 percent were classified as incompatible (Table 1). Within individual orchards, from 6 to 48 percent of the clones were incompatible, while within clones, from 4 to 95 percent of the ramets were incompatible. A general rule followed by many organizations has been to discontinue the grafting of any clone in which more than 50 percent of the ramets have been incompatible. On this basis, 62 of the 168 incompatible clones (37 percent) would have been discarded due to high incompatibility rates. Unfortunately, some of the select trees with the highest phenotypic superiority are also very highly incompatible. In this case, these high scoring trees must be abandoned since adequate numbers of grafts cannot be established for seed production.

Species Differences in Incompatibility

The mean percentages of incompatible clones in the other species were: slash - 26 percent, Virginia - 22 percent, shortleaf - 18 percent,

and pond - 30 percent (Table 2). Since these percentages did not vary appreciably from the loblolly mean of 22 percent, it would appear that there are no important differences in incompatibility between these five species under the conditions of this survey.

The only published data available on incompatibility in southern pines were reported by Allen (1967), who mentioned graft failures of 28, 6, and 33 percent for slash, loblolly, and shortleaf pines (respectively) after five years in the field. These data were based

TABLE 1

Incompatible clones by state and province: loblolly pine

<u>State</u>	<u>Province</u>	<u>Number of Orchards Repre- sented</u>	<u>Total Clones Grafted</u>	<u>Number of Incompat. Clones</u>	<u>Range of percent Incompat. Clones</u>	<u>Province Mean (% incomp.)</u>	<u>State Mean (% incomp.)</u>
Va.	Coastal	4	134	35	11-43	26	24
	Piedmont	2	64	12	13-29	19	
NC	Coastal	6	169	32	13-33	19	16
	Piedmont	5	116	14	10-18	12	
SC	Coastal	3	56	15	6-48	27	30
	Piedmont	2	43	15	21-46	35	
Ga.	Coastal	2	38	8	15-28	21	26
	Piedmont	2	42	13	28-33	31	
Tenn.	Mountain	2	41	8	20-21	20	
Ala.	Piedmont	<u>2</u>	<u>67</u>	<u>17</u>	<u>24-28</u>	<u>25</u>	
TOTAL		31	770	169	6-48	22	
Combined (Va, NC, SC, Ga.)	Coastal	15	397	90	6-48	23	
	Piedmont	11	265	54	10-46	20	

on a very small number of grafts, however, and incompatibility was not distinguished from overall mortality.

Graft incompatibility has been a serious problem in several other coniferous species. Losses in Douglas-fir (*Pseudotsuga menziesii*) due to graft incompatibility have been as high as 67 percent of the grafts established in one nine-year-old orchard (Wheat, 1967) and losses

continue to occur in 12-year-old orchards (Copes, 1968). Additional data from one orchard indicated that at eight years after grafting, 56 percent of the original grafts had survived, but 35 percent of these exhibited some scion overgrowth (Copes, 1967).

In clonal seed orchards in Rhodesia, 16 of 41 grafted clones of (Pinus patula) (39 percent) indicated signs of incompatibility, and 22 percent of the grafts planted failed due to this problem (Barnes, 1969). Incompatibility also remains a problem with slash, loblolly, and Monterey (P. radiata) seed orchards in Rhodesia.

Red pine (P. resinosa) scions grafted on Scotch pine (P. sylvestris) stocks in Canada were 36 to 46 percent incompatible although grafting survival was high (Holst, 1962). Interspecific and intergeneric graft combinations with (Pinus pinea) stocks have also exhibited good grafting

TABLE 2

Incompatible clones by species and state

<u>Species</u>	<u>State</u>	<u>Number of Orchards Repre- sented</u>	<u>Total Clones Grafted</u>	<u>Number of Incompat Clones</u>	<u>Range in % Incompat Clones</u>	<u>Species Mean % Incompat</u>
Slash	N. Carolina	1	16	10	62	26
	S. Carolina	2	54	5	6-11	
	Georgia	4	141	40	22-37	
	TOTAL	7	211	55	6-62	
Virginia	N. Carolina	1	20	7	35	22
	Tennessee	1	17	3	18	
	Alabama	1	23	3	13	
	TOTAL	3	60	13	13-35	
Shortleaf	Virginia	1	22	4	18	18
	N. Carolina	1	20	4	20	
	Tennessee	1	14	2	14	
	TOTAL	3	56	10	14-20	
Pond	N. Carolina	2	30	9	14-44	30

survival, followed by high rates of incompatibility (Baccari et al., 1967). Some interspecific grafts of (Pinus pinaster) on (P. pinea) were successful for as long as 12 years however.

In Australia, graft incompatibility has been reported with Honduras caribbean pine (P. caribaea, var hondurensis) and hoop pine (Araucaria cunninghamii), in addition to Monterey pine (Nikles, 1968).

Geographic Locations of Ortets, Stock, and Seed Orchards

In an effort to elucidate any geographic factors relating to incompatibility, the locations of all grafted ortets (compatible and incompatible) were plotted for a sample of 15 seed orchards (Figure 1). These orchards included grafts from 336 ortets extending from northern Virginia to central Alabama.

These plotted locations indicated that the ortets of incompatible clones were distributed strictly at random with no association between incompatibility and geographic province of the ortet or seed orchard location. In addition, the proximity of ortets to seed orchards did not insure compatibility, since of the 6 ortets which were located in the same county as a seed orchard, 4 were incompatible.

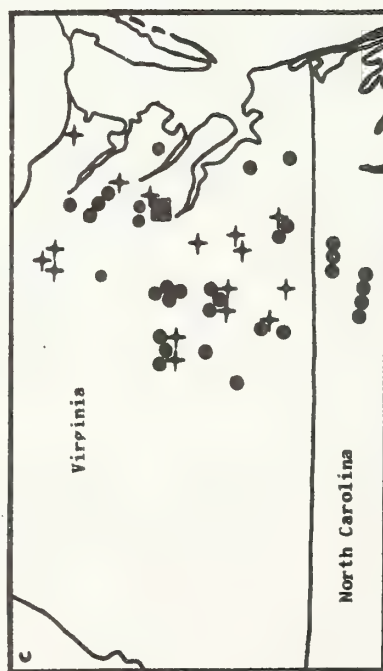
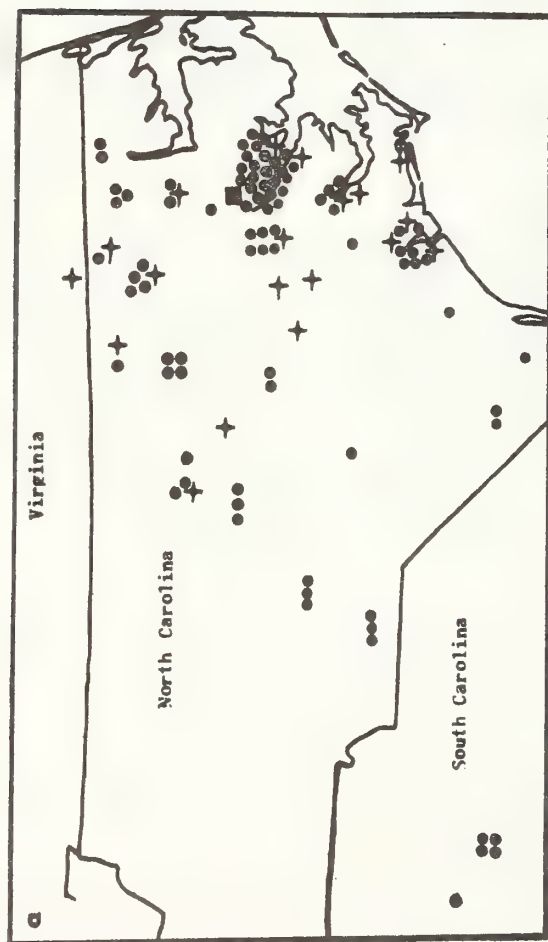
CONCLUSIONS

The Frequency of Graft Incompatibility

The widespread occurrence of graft incompatibility in many species, growing in a great variety of environments indicates that this phenomenon is not restricted to either "unusual" species or extreme environments. Every forest tree species which has been grafted in sufficient numbers has exhibited some graft incompatibility. The results of the North Carolina State University incompatibility survey indicating that 22 percent of the loblolly clones grafted have produced significant numbers of incompatible ramets, emphasizes the importance of the problem. The other four pine species sampled (slash, shortleaf, Virginia, and pond pines) demonstrated similar incompatibility rates. Although there are no comparable data on incompatibility rates in other species, the high overall mortality rates in Douglas-fir orchards suggest that incompatibility rates are higher in that species than in the southern pines.

Initiation and Development

The primary factor initiating graft incompatibility is the genetic difference between the stock and scion. Many environmental influences may modify these stock-scion differences, with resulting changes in the time and severity of symptomatic expressions of incompatibility, but these influences do not create an incompatible graft combination. The lack of incompatibility in autoplasmic grafts (stock and scion of the same genotype) of (Pinus pinea) (Baccari et al., 1967) and Douglas-fir (Copes, 1967) indicates that genetic differences between stock and scion are necessary for the initiation of incompatibility. Furthermore, these autoplasmic grafts suggest that the operation of grafting per se does not cause incompatibility.



Legend

- compatible ortet
- + incompatible ortet
- location of seed orchards

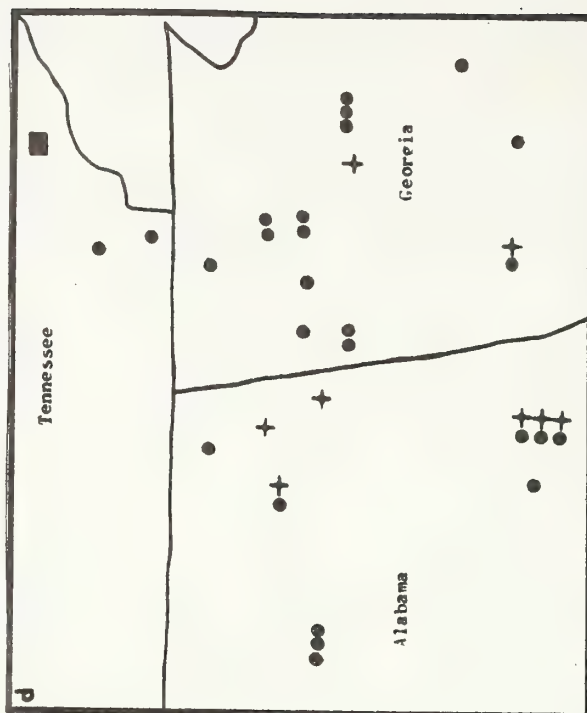
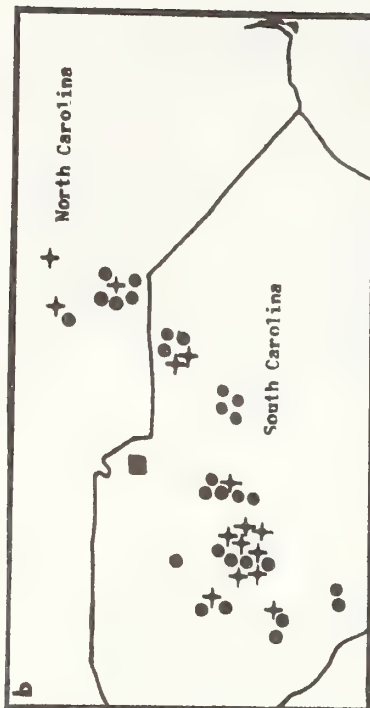


Figure 1. Locations of compatible and incompatible ortets

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ROOTSTOCK INFLUENCES EARLY FRUITFULNESS, GROWTH,
AND SURVIVAL IN LOBLOLLY PINE GRAFTS

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Abstract.--Scions from three loblolly pine clones were grafted on loblolly, slash, shortleaf, pond, and spruce pine rootstocks; and their performance was evaluated for 4 years. Scions on spruce pine roots grew more slowly and fruited earlier than those on other rootstocks, but their survival rate was poorer. Overall performance was best on slash pine roots. Rootstock had no effect on vegetative or reproductive phenology.

Additional keywords: Phenology, incompatibility, clone, Pinus taeda.

In most improvement programs for southern pine, grafted orchards are established from plus-tree scions. Much care is exercised in selecting scions, but surprisingly little consideration is given to the rootstock. In the study described here, rootstocks affected fruitfulness, growth, and graft compatibility in loblolly pines (Pinus taeda L.).

For more than a century rootstocks have been selected to enhance early production and to control size in fruit trees (Sax 1958). Recently Ahlgren (1962, 1972) found that in certain northern Pinus species rootstock not only influences strobili production and survival but also occasionally affects reproductive phenology. Research with shortleaf pines (P. echinata Mill.) showed that rootstock influences fruitfulness but not reproductive phenology (Schmidtling 1969, 1971).

MATERIALS AND METHODS

The ramets in the experimental orchard are scions from three loblolly clones, each grafted onto seedlings of loblolly, shortleaf, slash (P. elliottii Engelm. var. elliottii), spruce (P. glabra Walt.), and pond (P. serotina Michx.) pines. The three ortets are located in a 14-year-old plantation in southern Mississippi; they vary widely in size and fruitfulness, but have all flowered.

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Scions were top-cleft grafted on potted seedling rootstocks in January 1969. A total of 198 grafts were made, 13 or 14 of each of the 15 scion/rootstock combinations. In late May 1969, grafts were outplanted on the Harrison Experimental Forest at 15- by 15-foot spacing in a completely random design with single-tree plots.

Heights were measured and strobili counted annually. Ramets showing signs of incompatibility such as scion overgrowth or yellowing were considered non-survivors. Terminal bud elongation was measured three times a week from spring 1970, when growth began, until summer 1970, when growth ceased. In the springs of 1972 and 1973, female strobili were scored for receptivity two or three times a week during flowering. Strobili counts were normalized with the $\sqrt{x + 1}$ transformation. Differences in mean heights and strobili counts were tested by analysis of variance. Survival differences by rootstock were tested by chi-square. All statistical tests were at the 0.05 level of probability.

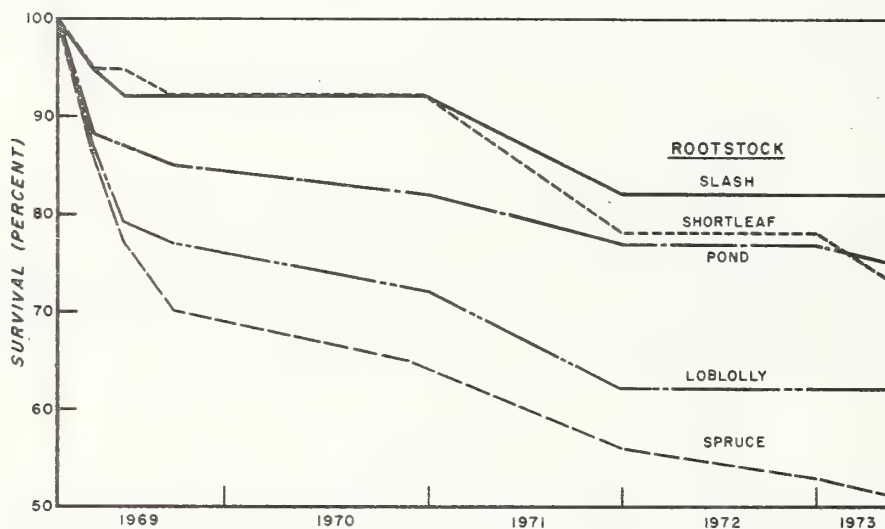


Figure 1.--Survival by rootstock of three loblolly pine clones grafted on five southern pine rootstocks.

RESULTS AND DISCUSSION

Survival

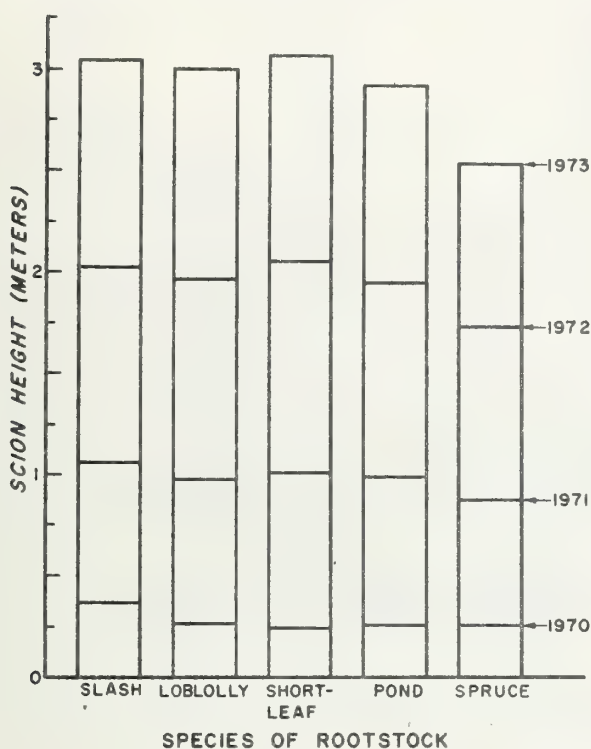
Initial graft take averaged above 90 percent and differed little between clones or rootstocks. By the winter after outplanting, considerable mortality had occurred (fig. 1). Currently, survival ranges from 82 percent on slash rootstock to 51 percent on spruce pine. Mortality in clones 2 and 3 was very light and varied little among rootstocks. Clone 1 suffered considerable loss due to incompatibility, and only 41 percent

of the ramets survived. Over 80 percent of the total mortality since outplanting resulted from losses in this clone. Unlike clones 2 and 3, survival in clone 1 varied considerably between rootstocks, with poorest results on spruce pine roots. Such findings are perhaps not surprising since spruce pine is not as closely related phylogenetically to the scion species as are the other rootstocks. If phylogenetic similarity is important, however, one would expect the best survival on loblolly rootstock. Actually, clone 1 survived best on slash rootstock (73 percent), with loblolly rootstock running a poor fourth (36 percent).

Although these survival data are preliminary, they do support conclusions derived from an 11-year study documenting improved survival of loblolly scions on slash rootstock (Schmidtling and Scarbrough 1970).

Height Growth

As anticipated, height growth differed significantly among clones. More importantly, heights differed significantly among rootstocks every year after outplanting (fig. 2). Initially growth was best on slash



rootstock, averaging 38 cm. the first year as compared to only about 23 cm. for all other combinations. This superiority soon disappeared. The most striking difference now apparent is the relatively small size of the scions on spruce pine rootstock (2.5 m.) in comparison with the others, which range from 2.9 m. for pond pine to 3.1 m. for shortleaf pine rootstock.

Allen (1967) also found significant differences in height growth 5 years after loblolly seedling scions were grafted on loblolly, slash, and shortleaf rootstocks. His height differences were larger than mine, probably because of the seedling origin of his scion material.

The rootstock x clone interaction was not significant, indicating that the rootstocks had approximately the same effect on the height growth of all clones.

Fruitfulness

Figure 2.--Height growth of three loblolly pine clones grafted on five southern pine rootstocks.

Rootstocks significantly affected numbers of female strobili produced in 1970 and 1972. The rootstock x clone interaction was never significant. Surprisingly, there were enough strobili for analysis in 1970 after only 1 year in the field. For the first 3 years, production was consistently best on spruce pine rootstock (table 1). The homoplastic combination (scion and rootstock of the same species) performed

poorly, and in 1972 the number of strobili per ramet on loblolly roots (2.4) was about half the number on spruce pine (4.7). Previous work with other Pinus species has also shown that heteroplastic grafts are generally more fruitful than homoplastic ones (Schmidtling 1969, Ahlgren 1972).

Table 1.--Female strobili produced by three loblolly pine clones on five southern pine rootstocks

Rootstock	Year			
	1970	1971	1972	1973
	-----Female strobili per tree-----			
Slash	0.19	0.03	3.56	45.1
Loblolly	0.07	0.08	2.42	40.4
Shortleaf	0	0.07	1.71	37.8
Pond	0.06	0.03	2.93	37.9
Spruce	0.68	0.33	4.68	29.4

In 1973, an extremely good year for female strobilus production in loblolly pines in south Mississippi, spruce pine-rooted ramets dropped from first to last place. Slash pine took the lead, with 45 strobili per ramet as compared to 40 for loblolly and 29 for spruce pine. The differences among rootstocks were not statistically significant. Apparently rootstock has a relatively minor effect in a year when a bumper crop of strobili is produced.

Clonal effects were significant every year except 1971. Clone 2, always the best producer, averaged 80 strobili per ramet in 1973. Clone 1 bore an average of 28 strobili per ramet in 1973. Clone 3 did not produce any strobili until 1972 and averaged only 8 strobili per ramet in 1973. Based on the performance of the ortets, fruitfulness was expected to be lowest in clone 1 rather than in clone 3. Clone 1's surprising fertility could be yet another manifestation of incompatibility since ramets often flower well under stress.

Phenology

No difference in vegetative phenology could be related to either rootstock or clone of scion. The elongation of the first flush was remarkably uniform. Variation developed in subsequent flushes, especially the third and fourth (when present); but no meaningful pattern was evident in initiation, duration, or number of flushes.

A distinct clonal effect was observed in female strobili development, but rootstock did not influence reproductive phenology in 1972 or 1973. Receptivity among rootstocks within an individual clone was very uniform.

Apparently rootstock does not affect phenology in loblolly pines as it does in Pinus cembra (Ahlgren 1972). Similarly, rootstock has little effect on the reproductive phenology of shortleaf pine (Schmidtling 1971).

CONCLUSIONS

Rootstock obviously influences height growth and fruitfulness in loblolly pines. In the past, loblolly was commonly grafted on slash rootstock for good take and vigorous early growth; but this practice was discontinued because of concern over possible incompatibility and effects on reproductive phenology. These fears now seem groundless. Loblolly scions survived and fruited better on slash than on loblolly roots, and rootstock had no effect on phenology. In fact, slash pine rootstock may be helpful in circumventing incompatibility. Since initial survival is best on this rootstock, its use could enable a tree breeder to complete controlled crosses and to retain a clone in a breeding program which would otherwise be lost.

Whether spruce pine rootstock is a good choice for loblolly scions is still questionable. Survival of one clone was especially poor on this rootstock. The induced early fruitfulness would be of value in a breeding program, and the smaller size could facilitate cone collection in a mature orchard. However, final evaluation can only be made when long term data on survival, growth, and fruitfulness are available.

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LIGHT TRAPPING IN SEED ORCHARDS UNDER A PEST MANAGEMENT SYSTEM

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Abstract.--Blacklight traps provide the seed orchard manager with a valuable tool for assessing insect populations that damage pine seed and cones. The identification, relative abundance, and biologies of insect species can be determined by operating only one light trap during the growing season. This information provides a basis for determining when controls are warranted and at what time they should be applied. Although the effect of using large numbers of light traps in a seed orchard has not been tested, such use might be valuable in depressing insect populations. If so, use of light traps might become useful as a control component in a pest management system for seed orchards.

Additional keywords: Insects, pine.

The first recorded use of light as an insect attractant was in Europe about 1787, when insect infestations were controlled in vineyards. Although the setup was very crude, the method used was essentially the same as the one used by present-day entomologists: the particular insect's positive reaction to light is taken advantage of to bring about its capture and destruction. More recently, light trapping has been used in attempts to control several agricultural pests attacking tobacco (Lam et al. 1968) and pecans (Tedders, Hartsock, and Osburn 1972).

PREVIOUS STUDIES IN SEED ORCHARDS

In 1968, work was begun at the Forestry Sciences Laboratory in Athens, Georgia, on the use of light traps in studying the adult activity periods, relative abundance, and geographic distribution of insects that infest pine seed and cones. These traps were operated during the same time that seed and cone insects were being sampled on selected trees throughout Clarke County, which surrounds Athens.

A light trap, based on the design of Barnes, Wargo, and Baldwin (1965), was selected for use in these studies. This trap consists of a 12-inch-high sheet-metal funnel 10 inches in diameter at the top and tapering to a 2-inch diameter at the base. A 10-inch square vertical baffle is attached to the top of the funnel. A 6-watt blacklight fluorescent light, horizontally mounted inside the funnel, projects light rays upward only.

Live specimens were captured in a polyethylene plastic bag designed to fit at the base of the light trap (Powers 1969). This bag was of sufficient size so that captured moths could move about with minimum injury and live, undamaged specimens could be used for further biological study. The traps were tied to a cord on a pulley attached to the lower tree crown and were lowered for collection of the nightly catches. If we did not desire to keep the insect

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specimens alive, the plastic bags were taken to the laboratory and placed in a chest-type freezer. Frozen specimens were in excellent condition for separation and identification.

We concentrated our trapping in a mixed plantation of loblolly (Pinus taeda L.) and shortleaf (P. echinata Mill.) pines in a residential development. The trees were about 40 feet tall and exhibited good growth and excellent yearly cone crops.

Each light trap was monitored for nine species of Lepidoptera that damage pine seed and cones. These included the phycitids Dioryctria amatella (Hulst), D. clarioralis (Walker), D. disclusa (Heinrich), and Dioryctria n. sp.; the olethreutids Laspeyresia toreuta (Grote), L. ingens Heinrich, Eucosma cocana Kearfott, and Rhyacionia spp.; and the geometrid Nepytia semiclusaria (Walker).

Similar light trapping studies have been conducted at Olustee, Florida, by Merkel and Fatzinger (1971). They have determined adult activity periods in northern Florida for D. amatella, D. clarioralis, and L. ingens. They have also determined the activities of two species--D. abietella (Denis & Schiffermüller) and L. anaranjada Miller--not found in the Georgia Piedmont.

Of the major insects known to attack pine seed and cones in the South (Ebel 1963, Goolsby et al. 1972), all have proven to be readily captured by light traps except for the seedbugs Leptoglossus corculus (Say) and Tetyra bipunctata (H.-S.), the cone midges of the family Cecidomyiidae, and the pine flower thrips of the order Thysanoptera.

During 1968, we also tested six commercially available fluorescent light sources to determine which was the most attractive to seed and cone pests (Yates 1973). These sources were designated as blacklight, blacklight-blue, white, warm-white, cool-white, and daylight. The blacklight and blacklight-blue sources were almost equally attractive to all the Lepidoptera that attack pine seed and cones. We have, however, standardized our trap light source in order to conform with that recommended by the Entomological Society of America: blacklight (ordering code F6T5/BL).

We have also studied the influence of trap height on insect catch and have determined at what hours during the night different species are trapped. Traps operated at 30 feet and 5 feet above the ground captured different insect species. Moths of the family Phycitidae, Dioryctria spp., were primarily captured in the 30-foot-high traps (D. amatella, 76 percent; D. clarioralis, 77 percent; D. disclusa, 74 percent; and Dioryctria n. sp., 76 percent). However, moths of the family Olethreutidae were captured primarily in the traps at the 5-foot level (L. ingens, 81 percent; L. toreuta, 89 percent; E. cocana, 65 percent; and Rhyacionia spp., 67 percent). The geometrid moth Nepytia semiclusaria showed no preference as to trap height (48 percent at the 30-foot level and 52 percent at the 5-foot level).

Insect catches were also recorded as to species during six 2-hour periods, beginning at 8:00 p.m. and ending at 8:00 a.m. each day. The olethreutids L. ingens and L. toreuta were captured primarily during the period from 8:00 p.m. until midnight. All four Dioryctria species showed peak periods of adult activity after midnight. For example, 84 percent of the D. amatella were captured between midnight and 8:00 a.m. This behavior is consistent with the

results of studies which show that, for Dioryctria spp., female "calling"--that is, the period when the females release their pheromone to attract the males--occurs about 2:00 a.m.

Light trapping has also been helpful in identifying the seasonal activity of cone and seed insects. Figure 1 summarizes the seasonal periods of adult flight for eight species of insects found in seed orchards in the Georgia Piedmont. The proportion of yearly catch is plotted above and below a baseline to emphasize the seasonal occurrence of the adults. These diagrams were developed by adding together the total number of each species trapped during the same weeks for 3 years. It should be emphasized that these individual diagrams were developed from 3 years' data and, because of yearly variations in seasonal weather, tend to be more dispersed in time than would diagrams for single years. However, the viewer can form an estimate of the likelihood of activity by a particular moth by referring to the relative thickness of its diagram at a given date.

These diagrams of adult catches provide a quick scan of the periods when adults are active and can be used as a guide to the timing of detection or control efforts. Second, they provide a ready reference to the adult biology of each insect, particularly by indicating the likely periods of greatest abundance and the number of generations each season.

LIGHT TRAPPING IN A PEST MANAGEMENT SYSTEM

The concept of pest management implies two things: first, that no attempt is made to eradicate a target pest and, second, that some damage to the protected crop is to be expected. This concept should not be hard for the seed orchard manager in the South to accept because, in some cases, his insect control efforts involving weekly or biweekly applications of large doses of pesticides have proven futile. The reasons for these all-too-frequent failures might include improper timing of spray application, use of untested pesticides or formulations, poor coverage, and an unfamiliarity with the pest fauna and the relative impact each insect species has on the ultimate crop.

In a pest management system, the manager does not generally rely on one method but rather integrates two or more methods to maintain a pest population at a tolerable level. Just how might light traps be used in a seed orchard under a pest management system? In many instances, the insect fauna which is a potential threat to seed production in a particular area is incompletely known. Yet specific insect determinations are essential in order to fully understand what menace exists and what course of action might be prescribed.

To illustrate, specific insect determinations based on the differences in cone damage caused by the olethreutid E. cocana and that caused by any one of the four phycitids D. clarioralis, D. disclusa, D. amatella, and Dioryctria n. sp. are difficult to make, even for those familiar with the damage symptoms. It would be futile to apply controls for E. cocana, which has one generation per year, when indeed the insect causing the damage is D. clarioralis, an insect species with three generations per year. Furthermore, E. cocana overwinters as a pupa in the duff under the trees, whereas D. clarioralis overwinters as a young larva on the shoots and cones.

TRAP CATCH

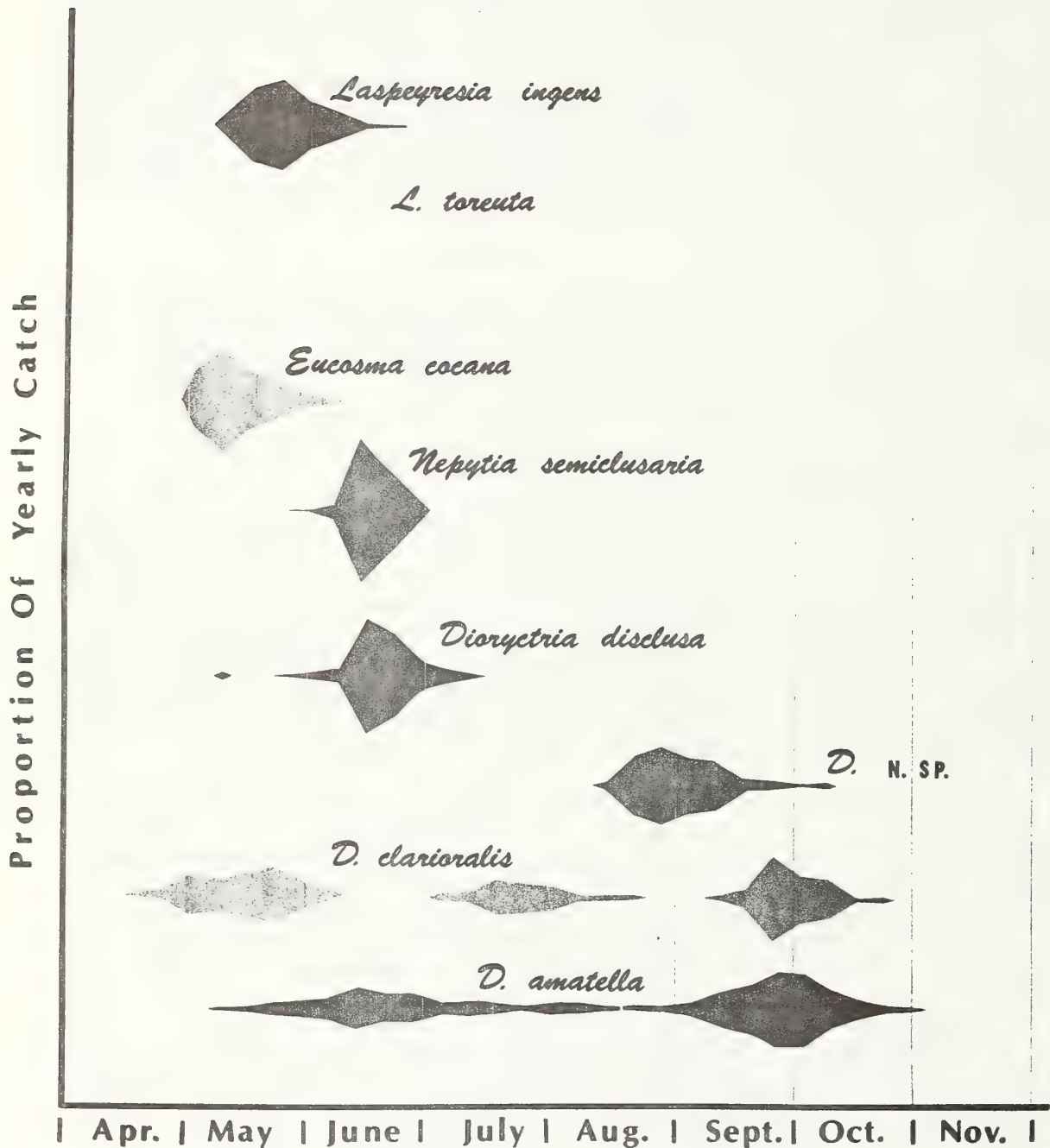


Figure 1.--Adult activity periods of eight species of cone and seed insects in the Georgia Piedmont as based on seasonal catches in light traps over a 3-year period.

Strategies to control these two species are for the most part incompatible, and a misidentification of the target species would result in wasted effort and money. Nightly light trapping would provide the seed orchard manager with adult specimens of the moths which attack the fruiting structures of pines in his area. He could then make tentative determinations by comparing specimens with colored illustrations, or he could submit suspect specimens to an entomologist for identification.

Similarly, once the insect complex in a particular area is known, an evaluation of each insect's potential impact may be made. On the basis of this information, a decision can then be made as to whether any action should be taken to manage a particular insect species. For instance, the work of Ebel (1971) indicates that the presence of the seedworms L. toreuta and L. ingens in seed orchards may be completely ignored: it is questionable whether a 3.8-percent gain in seed production would be sufficient to justify routine control efforts, even in a seed orchard.

Although extensive use of light trapping over a period of years has been demonstrated to reduce damage to agricultural crops (Tedders et al. 1972, Lam et al. 1968), this use has yet to be tested in seed orchards. The main obstacle to such an experiment appears to be financial. Over a period of 5 years, our light trapping in the same area of Georgia has shown that, for several species, there is a gradual yearly reduction in the overall numbers trapped each night. Unfortunately, no damage evaluations have been made that might relate these reduced insect captures to reduced damage to the seed crop. If the use of large numbers of light traps could be demonstrated to reduce damage to a tolerable economic level, then more direct control measures involving pesticides might be abandoned.

CONCLUSIONS

After 5 successive years of trapping seed and cone insects in the Georgia Piedmont, we are now able to verify observational knowledge about the biology of these insects. We also have gained considerable knowledge on how each insect species reacts to light sources and trap heights and on the periods of the evening when the various species are active.

Hopefully, these studies will lead to the incorporation of light trapping for insect detection in a pest management system for seed orchards. Reductions in catches during successive years of trapping in some instances suggest that population depression has occurred as a result of the trapping. If such population depression can be shown to result in reduced crop damage, then light traps might well become an important control component in a pest management system for seed orchards.

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HOW SEEDBUGS REDUCE THE QUANTITY AND QUALITY OF PINE SEED YIELDS

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Abstract.--The seedbugs Tetyra bipunctata(H.-S.) and Leptoglossus corculus(Say) are sucking insects that reduce the yield of pine seed by inserting their stylets into a cone and secreting enzymes into an ovule or seed. L. corculus destroys first-year ovules, and the conelets are aborted. Second-year cones that are fed upon may yield fewer seed or greater numbers of non-viable seed. The problems involved in detecting these losses in seed orchards are discussed. Data for several major species of southern pines are presented to illustrate the damage potential of seedbugs.

Additional keywords: Leptoglossus corculus, Tetyra bipunctata, Pinus echinata, P. taeda.

Cone production is reaching operational levels in many of the South's pine seed orchards, and with it comes increasing concern over the quantity and quality of seed yields. Tree improvement workers are well aware of the serious threat insects pose to the success of the seed orchard concept (Zobel 1971). Both orchardists and forest entomologists acknowledge the coneworms, Dioryctria spp., as a major pest problem in seed orchards. Although a multitude of insect species destroy the seeds and cones of southern pines, most orchard managers are familiar only with the more obvious types of losses. However, there are other insects which may have an equal or perhaps even greater effect upon seed production but go unnoticed because they operate in a more inconspicuous and subtle manner.

A shieldback bug, Tetyra bipunctata(H.-S.), and a leaf-footed bug, Leptoglossus corculus(Say), destroy pine seed but their mobility and the microscopic injury these sucking insects cause to attacked conelets and cones have hampered evaluations of their potential impact. This paper summarizes research devoted to answering the question of how seedbugs affect the quantity and quality of pine seed yields.

WHAT ARE SEEDBUGS?

Almost everyone recognizes at first meeting that T. bipunctata and L. corculus are stinkbugs. But to understand how these ubiquitous seedbugs limit seed yields of all the major species of southern pines, it is helpful to look at the differences between "true" bugs and the other, more familiar cone and seed insects. Seed orchardists frequently encounter damage caused by the larvae (immature stages) of moths, such as the seedworms, Laspeyresia spp. and the coneworms. Equipped with chewing mouthparts, these insects spend a large part of their life cycle within the cone, producing readily identifiable damage symptoms. In contrast, seedbugs feed externally, using hair-like sucking mouthparts called stylets to penetrate cones. Enzymes from the bug's salivary glands are secreted into an ovule or seed and the digested substrates are sucked up

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through the stylets. Consequently, the symptoms of damage are microscopic, and the seed losses are often attributed to causes other than insects.

Unlike most cone and seed insects, the seedbugs are hemimetabolous: they develop through five nymphal stages and then molt to the adult stage. There is no pupal (resting) stage, and the free-roaming nymphs are diminutive forms of the adult, lacking only the capabilities for reproduction and flight.

An important difference in the life histories of T. bipunctata and L. corculus greatly influences the relative damage potential of the two insects. Both species overwinter in the adult stage, but T. bipunctata is not found actively feeding in seed orchards until midsummer. The overwintering adults apparently undergo an obligate diapause, which limits the species to a single generation each year. In contrast, L. corculus is active early in the year (February in north Florida and April in north Georgia), and several generations occur per year. As a result of this difference in biology, L. corculus destroys pine seed in all stages of seed development.

SEED LOSSES DURING THE FIRST YEAR OF CONE DEVELOPMENT

Conelet drop or abortion commonly occurs on longleaf, Pinus palustris Mill., shortleaf, P. echinata Mill., and loblolly, P. taeda L., pines. In the past, the phenomenon has been referred to by such colorful names as "poop out" and "physiological drop." A search for insects which might play a role in the problem of conelet abortion led to the discovery of L. corculus and T. bipunctata as seed orchard pests (DeBarr 1967).

Although we knew that L. corculus nymphs feed upon conelets and that circumstantial evidence suggested a link with the problem of conelet abortion, it was not until 1971 that we demonstrated the insect's innate capacity to induce conelet abortion (DeBarr and Ebel 1973). In April, individual clusters of conelets were enclosed in small screen-wire cages to prevent feeding by natural field populations of seedbugs. Twenty clusters were caged on each of nine shortleaf pine trees. Clusters chosen at random were then artificially infested with laboratory-reared L. corculus nymphs or adults for 1-week periods during the early (May-June), middle (July-August), or late (September-October) portions of the growing season.

Nearly all conelets subjected to nymphal feeding aborted: 100 percent in the early period, 98 percent in the middle period, and 94 percent in the late period. Most of the caged conelets exposed to adult bugs survived without noticeable external effects. In a similar experiment on loblolly pine, 73 percent of the conelets aborted when exposed to midseason feeding by nymphs and 61 percent aborted when exposed to late-season feeding. No check conelets protected by cages during the 1971 growing season aborted.

Our work demonstrated that L. corculus nymphs have the inherent capability of inducing conelets to abort. The insect stage, number of nymphs, and timing of feeding periods used in our experiments were realistic from the standpoint of the biology of natural field populations of bugs. Although we do not infer that all conelet abortion is caused by bugs, the problem can no longer be considered to lie solely in the scope of tree physiology.

In a follow-up study of the abortion phenomenon, we exposed conelets to L. corculus nymphs, then dissected and sectioned conelets to verify that the

nymphs feed directly on first-year ovules (DeBarr and Kormanik, unpublished data). Most of the ovules in aborting conelets were destroyed. Therefore, it seemed likely that conelets which were fed upon by bugs but which did not abort would yield fewer seed per cone at harvest. This theory turned out to be true. Cones protected for 2 years except for a 1-week exposure to an artificial infestation level of two nymphs per conelet during the first year of development yielded about half as many total seed per cone as did cones never exposed to seedbugs (table 1). Conelets exposed to natural field damage by seedbugs but protected with cages during the second year of development also produced significantly fewer filled and total seed per cone.

Table 1.--Mean seed yields from loblolly pine cones exposed to *Leptoglossus corculus* nymphs during the first year of strobili development (Clark County, Ga., 1972)

Treatment	Filled (F)	Empty (En)	Total	Ratio of En:F+En
- - - -Seed/cone ^{1/} - - - -				
Caged for 2 years; exposed to two second-instar nymphs per conelet for 1 week in 1971.	46.2a	21.8a	68.0a	0.32
Caged second year only; exposed to field population of seedbugs as conelets.	58.8a	26.1a	84.9a	.31
Check--caged for 2 years; never exposed to seedbugs.	85.1b	37.4b	122.5b	.31

^{1/} Means not followed by the same letter are significantly different at the 5-percent level by Duncan's new multiple-range test.

It should be pointed out that although ovule destruction during the first year of development reduced the number of seed extracted at cone maturity, the ratio of empty:total seed per cone did not change (table 1). The empty seed were due only to fertilization failure (incompatibility), or other physiological causes, which occurred the second year, hence this ratio was unaffected by the random feeding of bugs on conelets.

SEED LOSSES DURING THE SECOND YEAR OF CONE DEVELOPMENT

Seed with endosperms damaged but not completely destroyed by *L. corculus* and *T. bipunctata* can be detected on radiographs of mature seed (DeBarr 1970). Observations with this technique indicated that damage to seed harvested in seed orchards of slash pine, *P. elliottii* Engelm. var. *elliottii*, was as high as 20 percent (DeBarr et al. 1972). However, some seedbug-damaged seed cannot be differentiated on radiographs from aborted or empty seed resulting from other causes, such as fertilization failure, especially when damage occurs before seedcoat development is completed.

The effects of feeding by L. corculus on cones during the second year of strobili development were also studied (DeBarr and Ebel 1973). Cone clusters were enclosed during May, before appreciable feeding was likely to have occurred from overwintering field populations of L. corculus adults. Cages were installed upon each of five loblolly and eight shortleaf pine trees in Clarke County, Ga. Again, bugs were introduced into cages during the early, middle, and late portions of the growing season. Check clusters were caged for the entire growing season. In addition, a sample of cones exposed to the local bug population was also collected from each tree at harvest.

Cones exposed to natural bug populations for the entire growing season or to artificial infestations of bugs for 1 or 2 weeks early in the summer yielded significantly fewer seed than did cones exposed during the middle or late periods. Seed damaged early in the season, before the seed coats had hardened aborted; the net result was fewer seed per cone at harvest.

In contrast, the total numbers of seed produced by cones exposed only to insects later in the growing season did not differ significantly from those produced by cones never exposed. This similarity reflects the fact that seedcoat development had progressed to the point where bug-damaged seed was collected as defective seed at harvest but, nevertheless, did contribute to the total seed yield per cone.

Full seed yields from cones exposed to natural bug populations for the entire growing season and cones exposed to artificial infestation levels of one bug per cone for 1 or 2 weeks early in the summer were drastically reduced in comparison with those from check cones. Loblolly pine cones protected only for the second year of development yielded 2-1/2 times as many filled seed as did cones exposed to natural bug populations, and almost 6 times as many full seed as did cones exposed to 2 weeks of bug feeding in the early treatment. The increase in full seed yield was even more dramatic for shortleaf pine. Cones caged only during the second year of development yielded 12 times as many full seed as did uncaged cones on the same shortleaf trees. These differences in yields, supported by evidence from the artificial infestation experiments, strongly suggest that heavy seed losses naturally occur in the early season from the feeding of L. corculus, thereby reducing the yield of viable seed per cone.

Feeding by L. corculus adults early in the summer also apparently had a systemic effect on cones. When measured and weighed at maturity, cones which had been exposed to L. corculus early in the season either naturally or in artificial infestations were significantly shorter and weighed less than protected check cones. In the study on shortleaf pine, which produces smaller cones than loblolly pine, feeding by L. corculus early in the summer actually caused some of the cones to die or abort.

THE TOTAL IMPACT OF SEEDBUGS IN SEED ORCHARDS

Leptoglossus corculus and T. bipunctata have an impact on seed yields during the first and second year of female strobili development. The known effects of seedbug feeding can be summarized as follows:

First-year conelets

A₁ = conelet abortion--extensive ovule damage; conelet withers and dies.

O₁ = ovule damage--conelet does not die; ovules are destroyed and seed are missing at harvest the following year.

Second-year cones

A₂ = cone abortion--extensive ovule damage; cone withers and dies.

O₂ = ovule damage--cone survives; ovules are destroyed and seed are missing at harvest; some may be extracted as flattened seed from mature cones.

E_b = empty seed resulting from seedbug feeding--seedcoat matures; seed produced is empty.

SB = seedbug-damaged seed--seed with damaged endosperm; can be detected on radiographs.

A sampling method for evaluating the total impact of seedbugs on orchard yields should account for all six categories of seed loss:

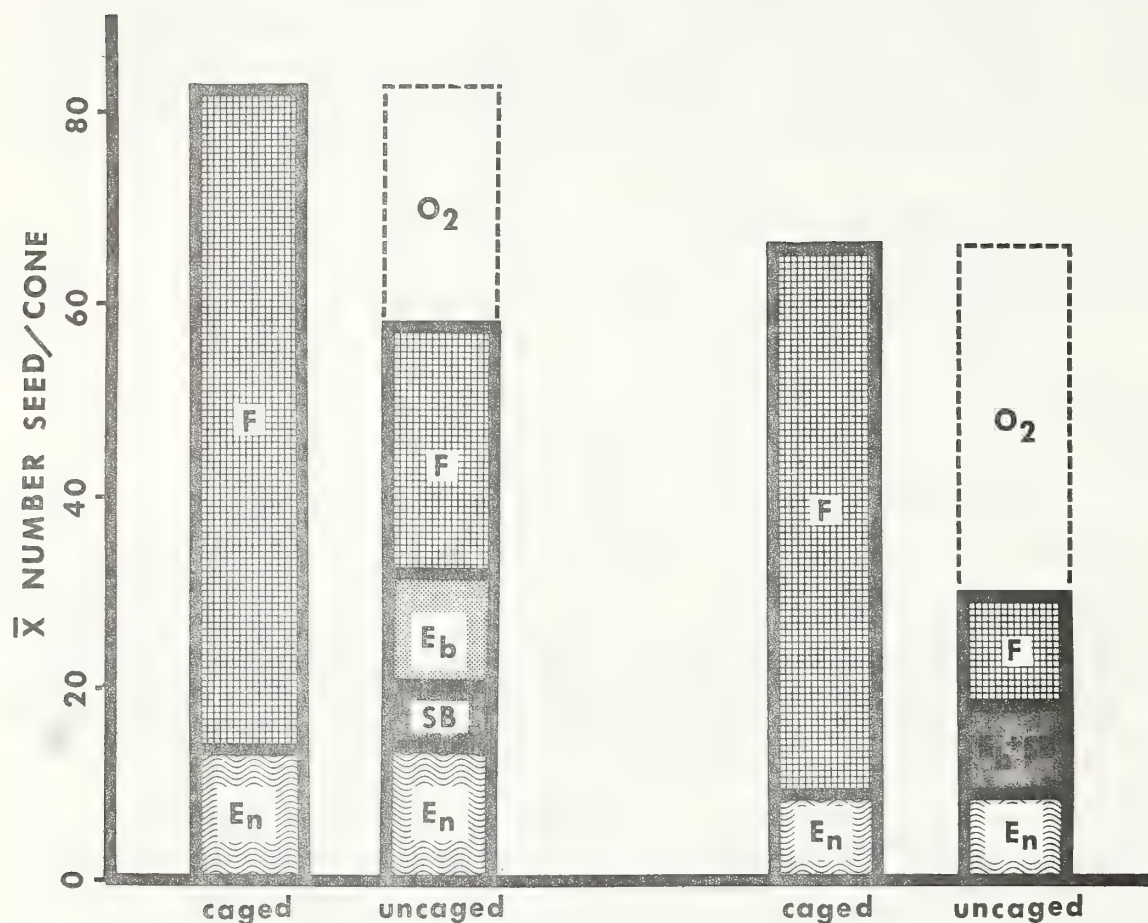
$$\text{Total seedbug impact} = A_1 + O_1 + A_2 + O_2 + E_b + SB$$

However, conelet (A₁) and cone (A₂) abortion will only be detected by periodic observations on tagged sample clusters. Even then, an unequivocal link between seedbug feeding and conelet or cone abortion cannot be made because of the lack of characteristic symptoms. Ovule destruction during the first (O₁) and second (O₂) years of development is reflected only by reduced yields of seed per cone. Once the seedcoat has hardened, seedbug damage is evidenced by an increase in the number of defective seed (E_b + SB) per cone.

The Eastern Tree Seed Laboratory is currently conducting a Seed Orchard Survey (SOS) of admirable magnitude and scope to determine the quantity and quality of seed produced in State, Federal, and industrial orchards. One facet of SOS is to evaluate seed losses resulting from insects. Seedbug-damaged seed (SB) are determined on radiographs of samples of mature seed. However, we now know that a substantial proportion of the total seed loss caused by seedbugs is not apparent under natural conditions at the time of seed harvest, and is overlooked or attributed to causes other than insects. The real impact of seedbugs on yields can only be determined when a potential yield base is available for comparison. Yields from protected (caged) cones provide such a base (fig. 1). Although SOS may show the relative losses among orchards, it must be considered as a very conservative estimate of the actual impact of L. corculus and T. bipunctata on seed orchard yields.

P. taeda-Clarke Co., Ga.

P. virginiana-Buckingham Co., Va.



O₂ = Ovule damage; seed missing.

F = Filled (Sound) seed.

SB = Seedbug-damaged seed (detectable by X-ray).

E_b = Empty seed (seedbug feeding).

E_n = Empty seed (physiological abortion).

Figure 1.--Quantity and quality of seed harvested in 1971 from protected and unprotected cones on the same loblolly and Virginia pine trees: protected cones were caged second year only; unprotected cones were exposed to natural populations of seedbugs for 2 years. Data on loblolly pine adapted from DeBarr and Ebel (1973); data on Virginia pine adapted from Bramlett and Moyer (1973).

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APPLICATION OF RADIOGRAPHY TO SEED
VIABILITY PROBLEMS IN YELLOW-
POPLAR SEED ORCHARDS

Russell A. Cox^{1/}

Abstract.--Cross-pollinated samaras from 25 clones in a yellow-poplar breeding orchard were subjected to radiograph and germination analysis. A high correlation was found between filled samaras identified by radiographs and samaras that germinated. Using clones as females, significant differences were observed among clones for percent filled samaras; no such differences were present among pollen parents. Viability tended to be higher when clones were cross-pollinated than when the same clones were open-pollinated.

The large number of seed of low viability (normally less than ten percent) produced by yellow-poplar (Liriodendron tulipifera L.) is perhaps the biggest problem face in a seed orchard made up of this species. The main objective of this study was to explore a method of nondestructive viability testing that could result in a reliable estimate of viable samaras for this species.

Pioneer work in the use of radiography in forest tree seed testing began in Sweden in the early 1950's. These researchers studied the usefulness and the effects of x-rays on the seeds of various forest species. Several properties of the seed sample, including percentage of filled seed and percentage of seed lacking embryos, could be diagnosed without destroying the seed sample (Simak and Gustafsson, 1953).

Practical application of techniques and refinement of methods during the 1950's transformed radiography from a laboratory oddity to a useful tool for testing forest tree seed. For instance, Klaehn and Wheeler (1960) reported on the possibility of radiography being of use in determining seed quality and observing embryo development of seed produced by various breeding methods. Taft (1962) used x-ray analysis to study the effect of controlled pollination on yellow-poplar seed quality. Many tree species that were difficult to analyse by other methods were readily adaptable to radiography. Proponents of this method of analysis have claimed that it is superior to other methods of viability testing due to its quickness and nondestructive characteristics.

The primary advantage to using radiography with yellow-poplar samaras is the conservation of the seed sample. This is particularly valuable when the seed subject to sampling are not available in quantity or are the result of carefully performed cross-pollination. X-ray negatives show clearly whether or not there is endosperm present within the samara. It has been established that if endosperm is present an embryo is also present (Wean and Guard, 1940). Therefore, it can be assumed that if endosperm is present, the samara is viable.

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METHODS AND PROCEDURES

Pollination of Flowers and Harvesting of Samaras

The technique used to acquire cross-pollinated samaras for this study was similar to that described by Wilcox and Taft (1969) and consists of emasculating an unopened flower bud and pollinating the exposed gynoecium with pollen from a desired source. Emasculation is carried out by choosing unopened buds, preferably just prior to natural opening, and removing the sheath of petals and stamens while leaving the gynoecium attached to the peduncle. At this stage receptivity of the stigmas is evident -- they appear slightly swollen and erect. Pollen from the desired clone is then brushed onto the exposed stigmas by using a detached and depetaled flower which is actively dehiscing.

Five pollinations were attempted for each cross on the same mother tree. Where five flowers were not available on one tree another ramet of the same clone was used. Crossing was done during the springs of 1970, 1971, and 1972 at the yellow-poplar seed orchard at The University of Tennessee.

Harvesting of samaras from controlled crosses was undertaken during the latter part of September for each of the three seasons encompassed by the study. Each group consisting of five pollinations (one cross) was collected and combined to provide a more reliable sample.

Radiograph Analysis

A sample of samaras was taken from each cross and placed in small cloth bags for stratification. Samples were soaked overnight, allowed to drain, and placed in cold storage at 32°-36°F for approximately 90 days. Following stratification each sample was mounted on an index card to allow for easy observation through the germination procedure. Stratified samaras were radiographed utilizing five by seven inch x-ray film under a General Electric Maxitron 300 x-ray unit. Best results were obtained using Dupont Cronex NDT 45 industrial film and x-ray unit settings of 70 KVp, 5 mA, and a focal distance of 75 cm. An aluminum filter (0.50 mm) was used to intercept hard x-rays that might have damaged the samaras. These specifications allowed for a dosage of 1.9 to 2.0 Roentgens, far below what is considered damaging radiation levels.

Data collection from the three seasons consisted of determining from the radiographs the percentage of filled samaras in each cross-pollinated sample. Each sample was then placed in a mist bench so that a measure of germination percentage could be obtained. At the end of a 50 day period the total number of germinations per cross were tallied and correlated with the number of filled samaras indicated by radiography.

In order to observe the effect of ionizing radiation on germination a study was undertaken which entailed exposing open-pollinated samaras to a wide range of doses of gamma radiation. Gamma radiation was used because of the similarity of its effect to x-radiation (Casarett, 1968) and the controllability of the cobalt 60 unit available. Twenty-four samples consisting of 500 samaras each from two clones were treated with six exposures ranging from 0 to 62500 Roentgens. After irradiation the samples were placed in a mist bench according to a split-plot design and allowed to germinate for 100 days.

RESULTS

Effect of Radiation

As illustrated by Figure 1, there is little difference in germination among the control, the 100R, 500R, and the 2500R treatments. However, somewhere between 2500R and 12500R there is a dosage that results in total death of the embryos. Exposures of this magnitude have little practical significance for radiography work because low doses of radiation are all that is necessary to produce a readable x-ray negative. Indeed, no adverse effect with respect to germination was noted at exposures up to and including 2500R (analysis of variance revealed no significant difference among the first four treatments). In fact, there seemed to be a slight stimulation of germination (not significant) as has been noted by previous authors (Simak and Gustafsson, 1953).

Reliability of Radiography

Approximately 1500 open-pollinated samaras on 15 seed mounts were examined by radiography. Each samara could be located on its seed mount by its position on the corresponding radiograph. All samaras were cut to determine if they were filled with endosperm. The reliability of the x-ray technique was tested by using regression analysis to obtain a sample correlation coefficient (r). For each of the 15 mounts, the number of predicted filled samaras found by x-ray was compared to the number of actually filled samaras found by cutting. The resulting correlation coefficient was 0.99, suggesting that one may consider the detection of filled samaras by radiograph as being very reliable; even those carpels filled with fungal mycelia did not register as full on the x-ray negatives.

Variation within the Gynoecium

Five ripe, but still entire, gynoecia were collected from each of three open-pollinated clones. Samaras from these clones were mounted on index cards in order of their occurrence from the topmost samara to the last basal samara on the central spike. Ten zones were established for each seed mount: Zone one consisted of the topmost ten percent of samaras from a gynoecium and likewise down the central spike including the basal samaras. This arrangement placed the great majority of basal samaras in zone ten.

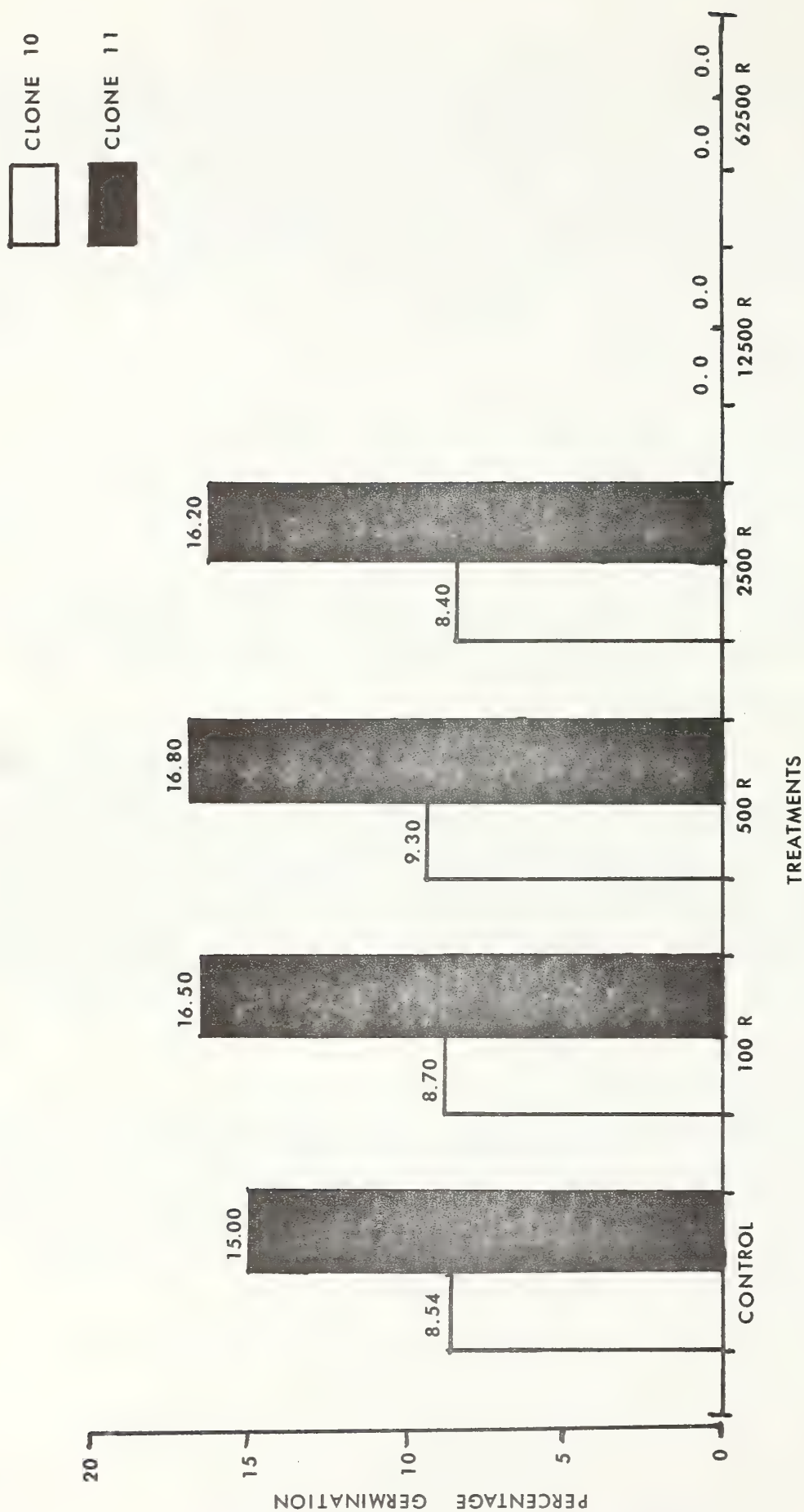


Figure 1.--Mean effect of gamma radiation on the germination of yellow-poplar samaras from two clones.

The number of filled samaras were counted from radiographs and compiled for each zone on all gynoecea. Figure 2 pictures the results of compiling the zonal means for all three clones. Zone one rarely contains viable samaras and zone ten can be considered as consistently sterile in this study. There seemed to be little tendency toward higher or lower viability within the remaining zones.

Radiography of Crosses and Results of Analysis

Data from radiograph analysis and subsequent germination were collected for two seasons. The sample correlation coefficient (r) for the first season was 0.803 ($r^2 = 0.644$) which indicates that 64.4 percent of the variance in the sample was due to the regression of filled samaras on samaras that germinated (Snedecor and Cochran, 1967). The same analysis for the second season resulted in an " r " value of 0.869 ($r^2 = 0.756$) indicating that 75.6 percent of the sample variation for that season was explained by the described regression.

One of the more outstanding factors explaining the somewhat low " r " values for these two seasons is the tendency for yellow-poplar samaras to fail to break dormancy after the first cold storage treatment. In fact, under natural conditions samaras have been recorded to have remained viable for four years in forest litter (Clark and Boyce, 1964).

Although the harvest of the third season of the study was not germinated in the mist bench, the various crosses were radiographed following the procedure of the previous year. This provided the study with three years of data with respect to filled samaras. Examination of these data revealed that 15 out of the 25 clones used during the three seasons were crossed with sufficient regularity to be used in an analysis of variance. The mean percentage filled samaras of each mother parent crossed by several distinct pollen parents was computed. These means are given in Table 1.

Using the three years as replications and the different clones used as females as treatments a simple analysis of variance was performed. The results indicated no significant difference among years but a highly significant difference among clones.

An analysis of variance was also performed for those clones used regularly during the three seasons as pollen parents (as it turned out 12 of the 25 clones were used during all seasons). The results of this analysis revealed no significant difference among years or clones. A further difference between the female and the pollen parent clones is the range of viability. Three year means for female clones range from 4.6 percent to 34.5 percent, comparable with results obtained by Thor (1966). Pollen parent clones range from 10.3 percent to 19.3 percent (Table 1). Considering these findings, one is inclined to conclude that the viability level of a given cross is primarily controlled by maternal factors. This is in agreement with the suggestion of other authors that incompatibility and subsequent low seed viability is caused by a chemical incompatibility between the style of the mother parent and the pollen tube of the pollen parent (Kaeiser and Boyce, 1962).

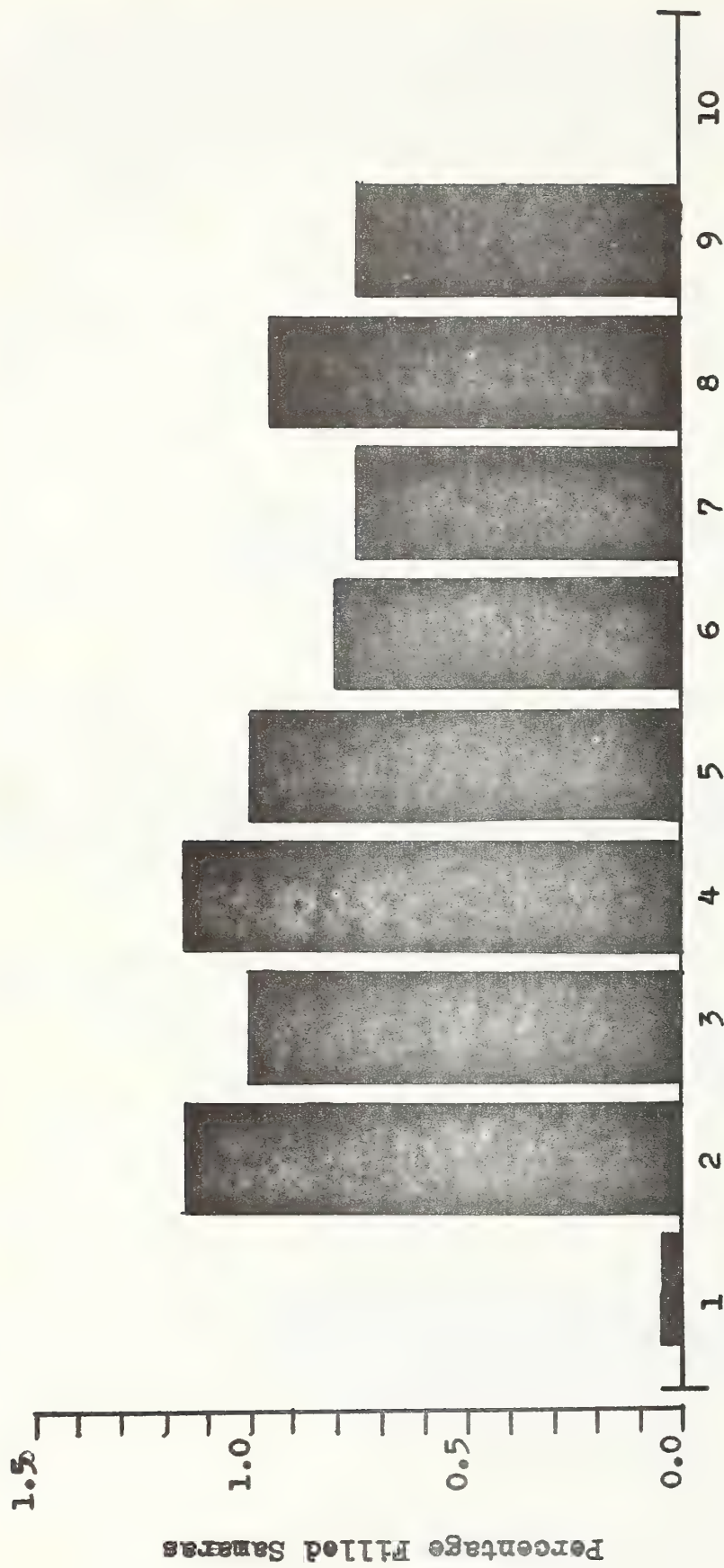


Figure 2.--Zonal means for all gynoechia from three open-pollinated clones.

Table 1.--Mean percentage filled samaras obtained from controlled crosses in three seasons

Clone	----- Percentage -----							
	1970		1971		1972		Means for 3 seasons	
	♀	♂	♀	♂	♀	♂	♀	♂
1	14.0	-	14.1	-	12.3	-	13.5	-
2	8.5	17.0	8.9	6.9	10.5	18.6	9.3	14.1
3	11.5	12.6	1.6	7.5	10.9	23.2	8.0	14.4
4	0.5	13.2	5.1	17.7	10.0	17.4	5.2	16.1
5	24.7	17.8	23.1	8.2	24.6	11.2	24.1	12.4
6	4.0	-	3.4	-	6.5	-	4.6	-
11	34.6	17.2	32.4	22.0	36.4	18.8	34.5	19.3
12	2.0	-	22.4	-	15.6	-	13.3	-
13	27.4	8.1	21.0	8.0	13.4	17.7	20.6	11.3
16	10.8	12.4	11.7	16.4	14.3	27.7	12.2	18.9
22	11.3	17.2	4.2	20.8	5.2	11.2	6.9	16.4
27	9.0	18.4	6.9	19.6	14.1	11.4	10.0	16.5
31	22.8	11.7	9.7	4.8	11.0	17.8	14.5	11.4
35	-	7.0	-	15.4	-	8.7	-	10.4
39	10.0	-	12.1	-	14.4	-	12.2	-
108	14.1	10.0	15.7	9.0	15.1	18.6	14.9	12.5
Means	13.7	13.6	12.9	13.0	14.3	16.8	13.6	14.0

An analysis similar to that done for the means of cross-pollinated clones was performed for eleven open-pollinated clones found in the same orchard. The results of this analysis indicate no significant difference among years at the ten percent level but significant difference among clones at the same level. Clonal means varied from a low of two percent filled samaras to a high of 18 percent, with a mean of 8.6 percent. This mean is considerably lower than the 13.7 percent obtained for the cross-pollinated samaras. However, the clones producing samaras with high viability when cross-pollinated also produced a high percentage of filled samaras when open-pollinated.

CONCLUSIONS

The findings of this study indicate that radiography can serve as a useful tool to the tree improver. For instance, the analyses of variance indicate that there is enough difference among clones in the orchard to warrant removal of some clones with lower seed viability. Removing the poorest one quarter of the clones from this orchard will increase percentage filled samaras from 8.6 to 10.3; an increase of nearly 20 percent.

STIMULATION OF FLOWERING IN SWEETGUM

J.B. Jett and George Finger^{1/}

Abstract.--A study was undertaken in 1969 to stimulate flowering in a seven-year-old clonal sweetgum seed orchard which had to that time been essentially non-productive.

Four treatments, consisting of two forms of nitrogenous fertilizers, a chemical growth retardant and a control, were randomly applied to four non-flowering ramets of four clones and replicated four times.

Results indicate that both ammonium nitrate and diammonium phosphate were very effective in stimulating flowering. Use of the chemical growth retardant "B995" provided no meaningful stimulation of flower production.

Based upon results of this study, the orchard has received an operational mid-summer application of ammonium nitrate in 1970, 1971, and 1972. Subsequent flower crops have been excellent. However, the bulk of the last two flower crops has been lost due to late spring frosts. The possibility exists that the heavy applications of nitrogenous fertilizer have increased susceptibility of sweetgum flowers to cold damage.

Additional keywords: Fertilization, growth retardants, Liquidambar styraciflua.

The high establishment and maintenance costs of a seed orchard make it mandatory that early and abundant seed yield be obtained as quickly as possible. Methods to accomplish this are fairly well understood for the pines, but information for the hardwoods is limited. Although at present there are few hardwood seed orchards in the south, it is important to determine the management techniques required to insure productivity of existing and anticipated orchards.

Attempts to stimulate seed production in forest tree species have generally involved either the application of soil amendments or some form of plant mutilation. In numerous instances soil amendments have been shown to significantly increase seed production of coniferous species. Heavy application of nitrogen, and frequently phosphate, have produced the most dramatic results. Plant mutilation, involving practices such as stem strangulation, partial girdling, bark-ring inversion and root pruning, are occasionally sufficient to initiate flowering but the effects are normally temporary. Additionally, mutilation increases the risks of insect and disease attack, thereby limiting its usefulness. Although commonly used on several horticultural crops to stimulate or regulate flowering, chemical growth retardants have received little attention for use on forest tree species.

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The current investigation was undertaken to stimulate flowering in a clonal sweetgum (Liquidambar styraciflua L.) seed orchard using two forms of a nitrogenous fertilizer and a chemical growth retardant. The orchard belonging to Weyerhaeuser Company, and located at Washington N.C. was seven years old at the initiation of the study and was essentially non-productive. The soils in this orchard are loam underlain by clay at depths of from 6 to 15 inches and are moderately to poorly drained. Fertilization prior to this study consisted primarily of annual applications of a balanced fertilizer, such as 10-10-10, at an average rate of approximately 200 pounds per acre.

METHODS

Four treatments, replicated four times, were randomly applied to four non-flowering ramets of four clones the first week of June, 1969. Treatments consisted of the following:

- A. Diammonium phosphate (DAP); applied at the rate of one-half pound per inch of basal stem diameter to an area within the crown drip-line.
- B. Ammonium nitrate (NH_4NO_3); same rate and application as for the diammonium phosphate.
- C. Growth retardant "B995" (succinic acid 2, 2-dimethyl hydrazide)^{2/} two applications separated by an interval of two weeks in a solution of 5000 ppm applied to the point of run-off from the foliage.
- D. Control - no treatment.

The total height of each tree was measured at the initiation of the study and subsequent remeasurement was made at bi-weekly intervals throughout the growing season. The effectiveness of the treatments to initiate flowers was evaluated during the spring of 1970. A total count of all flowers on each treated ramet was made as soon as flowers and floral buds were readily distinguishable from vegetative buds.

The analyses of variance for the effect of treatment on flowering and on height growth follow a factorial arrangement. Components of error were pooled to provide a single error term for testing the significance of main effect differences and the treatment x clone interaction term.

RESULTS AND DISCUSSION

Results of the analysis of variance for flowering (Table 1) indicate that highly significant differences exist among treatments, and among clones, and significant differences exist for the interaction of treatments x clones.

^{2/} Provided by the United States Rubber Company - Chemical Division

Table 1. --Analysis of variance for the effects of nitrogen fertilizer and a growth retardant upon flowering of sweetgum

Source	df	SS	MS	F ^{a/}
Replications	3	64846	21615	
Treatments	3	722127	240709	8.99**
Clones	3	572837	190946	7.13**
Treatments x clones	9	550246	61138	2.283*
Error	45	1205053	26778	

a/ *Statistically significant at the .05 level

**Statistically significant at the .01 level

A comparison of the mean number of flowers per ramet for each treatment (Table 2) reveals that the two fertilizer treatments were significantly more effective in stimulating flowering than was the "B995", and that there were no significant differences between the forms of nitrogenous fertilizer used despite the large differences in number of flowers per ramet (240.69 versus 179.19) for ammonium nitrate and diammonium phosphate, respectively. From a biological and practical sense the difference among fertilizer treatments is very real. If differences of this magnitude were consistently obtained, most orchard managers would favor the ammonium nitrate over diammonium phosphate.

Table 2. --Mean number of sweetgum flowers per ramet by treatments

Treatment	Mean number of flowers
NH ₄ NO ₃	240.69
DAP	179.19
"B995"	3.38
Control	0.62

L.S.D. (.05) = 116.52 flowers. Means not connected by the same vertical line differ significantly

As expected, clonal response differences and the clone x treatment interactions were statistically significant (Table 1). The magnitude of clonal response is indicated in Table 3.

Table 3. --Mean number of sweetgum flowers per ramet by clone

Clone	Mean number of flowers
3	268.56
20	64.69
4	57.62
5	33.00

L.S.D. (.05) = 116.52 flowers. Means not connected by the same vertical line differ significantly

Such clonal differences in response to fertilizers have been well established for several coniferous species, Croker (1964), Schultz (1970), Shoulders (1967), and Swan (1964). Based upon accumulating evidence obtained in loblolly pine (*P. taeda* L.) seed orchards, it appears that fertilization increases the differences between clones with different flowering intensities (Bergman, 1968).

Height growth also showed a differential response to treatment (Table 4).

Table 4. --Analysis of variance of the effects of nitrogen fertilizers and a growth retardant upon height growth of sweetgum

Source	df	SS	MS	F ^{a/}
Replications	3	.5355	.1785	
Treatments	3	6.0929	2.0310	15.236**
Clones	3	2.1293	.7098	5.325**
Treatment x clones	9	2.5564	.2840	2.131*
Error	45	5.9970	.1333	

a/ * Statistically significant at the .05 level

** Statistically significant at the .01 level

Clonal differences as well as those of clone x treatment interaction were significant at the .01 and .05 level, respectively. However, the range in mean height growth per ramet by treatments was 1.06 ft. to 0.33 ft. (Table 5), representing a difference of only 0.73 ft. between the high effect of ammonium nitrate and the low effect of "B995". It is doubtful that this difference has any real practical implication. Results obtained from a fertilization study in Catawba Timber Company's loblolly seed orchard revealed that height was not affected by treatment, while diameter increased directly with fertilization and irrigation, (Anonymous, 1972). Gregory (1968), working with loblolly pine seed orchards, reported that seed production could be stimulated by irrigation and fertilization without unduly increasing height growth of the trees. He observed that, while there was no significant increase in height growth, the trees did exhibit a significant

increase in diameter growth following fertilization. Diameter measurements were not obtained in this study on sweetgum and consequently no assessment can be made of this growth aspect.

Table 5.--Mean height growth for all clones by treatments

Treatment	Mean height growth (feet)
NH ₄ NO ₃	1.06
DAP	0.98
Control	0.50
"B995"	0.33

L.S.D. (.05) = 0.26 feet. Means not connected by the same vertical line differ significantly

Numerous examples of differential growth of clones for coniferous species exist in the literature (Zobel and Roberds, 1970). Genotype-x-fertilizer interactions for hardwoods have been reported for (Populus deltoides Bartr.) which exhibited differential growth response among clones (diameter, height, and volume) to nitrogen fertilization (Curlin, 1967) and for sycamore (Platanus occidentalis L.), where 48 open-pollinated families responded differentially to nitrogen fertilization (Kitzmilller, 1972).

As for flowering, the data from this study indicate that there are clonal responses to treatments (Table 6), with one clone responding much more than did the other three. However, the differences among the four clones represented in this study are relatively small.

Table 6.--Mean height growth (feet) per ramet by clone

Clone	Mean height growth (feet)
3	1.02
4	0.68
20	0.59
5	0.58

L.S.D. (.05) = 0.26 feet. Means not connected by the same vertical line differ significantly

CONCLUSIONS AND SUMMARY

Results from this study indicate that both ammonium nitrate and diammonium phosphate were very effective in stimulating flower production of seven-year-old

sweetgum grafts. Based upon these results, it has become routine management in this sweetgum orchard to apply a midsummer application of 200 pounds of ammonium nitrate per acre. Flower crops following this fertilization regime, begun in 1970, have been excellent. However, the bulk of the flower crops in 1971 and 1972 was lost to late spring frosts. There is a possibility that the heavy applications of ammonium nitrate have increased susceptibility to cold damage, either by making the sweetgum more succulent or causing earlier than normal flower formation.

Most dicotyledonous plants are responsive to "B995" with the most obvious effect^{4/} being a reduction in vegetative growth through reduced internode elongation. Among other reported "side" effects are an increase in the number of flowers and promotion of floral buds. The theory behind the flower stimulation effect of growth retardant "B995" provided no meaningful flower stimulation and no significant retardation of growth.

Although not included as a treatment in this study because of the limited amount of material available, an additional growth retardant, UNI-F529, was applied to 12 ramets of a fifth, non-flowering clone at a rate of 2500 ppm.^{5/} UNI-F529 (N - pyrolidino - succinic acid), is reported to be more persistent in its effects during the summer months than "B995" (Cathy, 1969). Normally, UNI-F529 applied at one-half the dosage of "B995", is reported to produce similar growth retarding effects. Based upon observation only, no detectable differences in the performance of the two chemical retardants could be seen. The 12 ramets treated with UNI-F529 produced a total of 40 flowers versus 54 flowers on 20 ramets treated with "B995".

In summary, the use of nitrogenous fertilizers to stimulate flowering of sweetgum is a highly successful, efficient orchard management tool. Not only was flower production initiated and maintained, but the general health and vigor of the entire orchard was improved.

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EARLY FLOWERING IN CHERRY:
EFFECTS OF GENOTYPE, ENVIRONMENT AND CHEMICAL GROWTH RETARDANTS

Paul E. Barnett and Robert E. Farmer, Jr.¹

Abstract.--In a series of tests with juvenile Prunus serotina, growth retarding chemicals (Alar, CCC, Ethrel), long-day greenhouse conditions and drought did not stimulate flowering. All seedlings from a low elevation source flowered in pots within two years from seed, regardless of chemical or environmental treatment; no high elevation seedlings flowered under similar conditions. Flowering observations in a three-year-old planting of black cherry confirmed this relationship between early flowering and altitudinal provenance. In a comparison test Prunus besseyi seedlings flowered prolifically after their first season's growth and P. virginiana after two seasons.

INTRODUCTION

The normally long juvenile period exhibited by most forest tree species has generated a search for practical ways of shortening the breeding cycle. Research on this problem was most recently reviewed by Zimmerman (1972), who surveyed results from a number of experimental approaches. Investigation of environmentally induced flowering has generally supported the notion that sexual maturity is dependent upon attaining a certain size and morphological complexity (e.g., Longman and Wareing, 1959; Zimmerman, 1971). There is also increasing evidence that duration of the juvenile period is genetically controlled (e.g., Greene, 1967; Johnsson, 1949; Visser, 1965). The success of floral induction in some ornamental shrubs with growth retarding chemicals (Stuart, 1961; Marth, 1963) has led to trials with juvenile trees which have so far produced generally unpromising results (Zimmerman, 1972).

We report here a series of tests aimed at evaluating the influence of growth retardants, several environmental conditions, and genetic composition of material on early flowering of black cherry (Prunus serotina Ehrh.) and two shrub cherries (sand cherry P. besseyi (Bailey) G.I. and choke cherry P. virginiana L.).

TEST I

A test including 12 six-tree replications of nine treatments (Table 1) was established in the spring of 1968 with three-year-old black cherry seedlings (western North Carolina seed origin), to study effects of Alar (N-dimethylamino succinamic acid) and CCC (2-chlorethyl trimethyl ammonium chloride) foliar sprays on growth and flowering. Freshly prepared aqueous solutions were applied in early morning. The seedlings were growing vigorously on an alluvial site in Anderson County, Tennessee, which received 1000 pounds per acre of 15:15:15 fertilizer in both 1966 and 1967.

No treatment significantly reduced growth relative to controls (Table 1), although trees treated with 4000 ppm Alar grew less than those treated with CCC. Some rosetting was noted on lateral branches, but height growth was vigorous during the spring. Although some trees stopped growing briefly in July, late July rains caused resumption of apical growth until late August. In the spring of 1969 a single tree in Treatment 2 flowered; in the spring of

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1970 two trees flowered. The planting has been maintained without further treatment and less than 5 percent of the trees flowered in 1973, when they were 5 to 10 meters in height.

Table 1. Height increment (in 1968) of black cherry seedlings as influenced by spray treatment with growth retardants

<u>Treatment</u>	<u>Height Growth (Centimeters)</u>
(1) Control	52
(2) Alar, 4000 ppm. One application immediately after leaf expansion and two additional applications at two-week intervals.	34
(3) Alar, 1000 ppm. Applied as in Treatment No. 2.	52
(4) Alar, 4000 ppm. One application at one month after leaf expansion and three additional applications at one-week intervals.	37
(5) Alar, 1000 ppm. Applied as in Treatment No. 4.	46
(6) CCC, 4000 ppm. One application immediately after leaf expansion and two additional applications at two-week intervals.	67
(7) CCC, 1000 ppm. Applied or in Treatment No. 6.	55
(8) CCC, 4000 ppm. One application at one month after leaf expansion and three additional applications at one-week intervals.	64
(9) CCC, 1000 ppm. Applied as in Treatment No. 8.	85

TEST II

Objectives of this test were to (1) induce early flowering in cherry by growing seedlings rapidly in a greenhouse environment, and (2) evaluate the effect of Alar on growth and flowering under two environmental conditions.

In April 1968, 60 one-year-old seedlings each of black cherry (eastern Tennessee source, altitude unknown), choke cherry (Pennsylvania source), and sand cherry (North Dakota source) were planted in 10-gallon plastic pots filled with a loam soil. Stems were pruned to a height of eight cm. Choke cherry and sand cherry were used because they flower early in ontogeny under natural conditions and were considered potentially good experimental material. Seedlings were divided into four groups of 15 each and assigned to the following treatments:

1. Seedlings grown under long-day (18 hours) greenhouse conditions.
2. Same as 1, treated periodically with a soil drench of 4000 ppm Alar.
3. Seedlings grown outdoors under normal day-length conditions.
4. Same as 3, treated periodically with a soil drench of 4000 ppm Alar.

During the summer of 1968, Alar treatments were applied on July 4, 8, 19, and August 4. Height was measured biweekly throughout the growing season. By early September apical growth of all plants had stopped. In mid-October, after trees in outdoor treatments were naturally defoliated, all plants were placed in an unheated basement for overwintering.

Treatments 1 and 2 were returned to the greenhouse on March 10, 1969, and observations of foliation date and flowering were recorded. By May 8, it was necessary to move all plants out of doors because of the height attained by some of them.

In April 1969, foliation and flowering observations were recorded for plants in Treatments 3 and 4, which were moved out of doors from the chilling room in mid-March. During the 1969 growing season Alar treatments began in mid-May and were applied at weekly intervals until late June. By this time all plants had stopped apical growth after shoot increments of 50 to 60 cm. Plants overwintered out of doors, and flowering observations were recorded in the spring of 1970.

The 1968 growth pattern for black cherry is presented in Figure 1; patterns for the other species were similar. Many Alar-treated plants exhibited the rosette apex typical of growth retardant effects. Typical plants of all three species are shown in Figure 2.

Sand cherry foliated first in the spring of 1969 and all plants flowered profusely regardless of treatment. Alar-treated plants of both black and choke cherry began growth earlier than control plants. Twenty percent of the choke cherry plants treated with alar flowered regardless of environment; seven percent of controls grown out of doors flowered, but none grown in the greenhouse flowered. No black cherry trees flowered in 1969.

All choke cherry trees grown out of doors during the entire test flowered prolifically (50 or more racemes per tree). Plants initially grown in the greenhouse and moved outside later flowered less abundantly, with slightly more Alar-treated plants flowering than controls (53 vs 33 percent). A few black cherry trees (13 percent) grown out of doors flowered while none initially grown in the greenhouse did so.

TEST III

Effects of Alar and Ethrel (2-chloroethyl phosphonic acid), moisture stress, and source of stock were studied in a factorial test. Forty black cherry seedlings from a high elevation (1,100 to 1,370 meters) source and the same number from a low elevation (275 to 365 meters) source in Madison County, Tennessee, were established in 15 cm. pots during March 1970. Eight plants from each of five open-pollinated families from each source were included. Seedlings were grown in a greenhouse until May when they were transplanted to 33 and 43 centimeter metal pots containing loam soil and grown out of doors for the remainder of the season. After winter chilling out of doors, some low elevation trees flowered in the spring of 1971 (Farmer and Barnett, 1972).

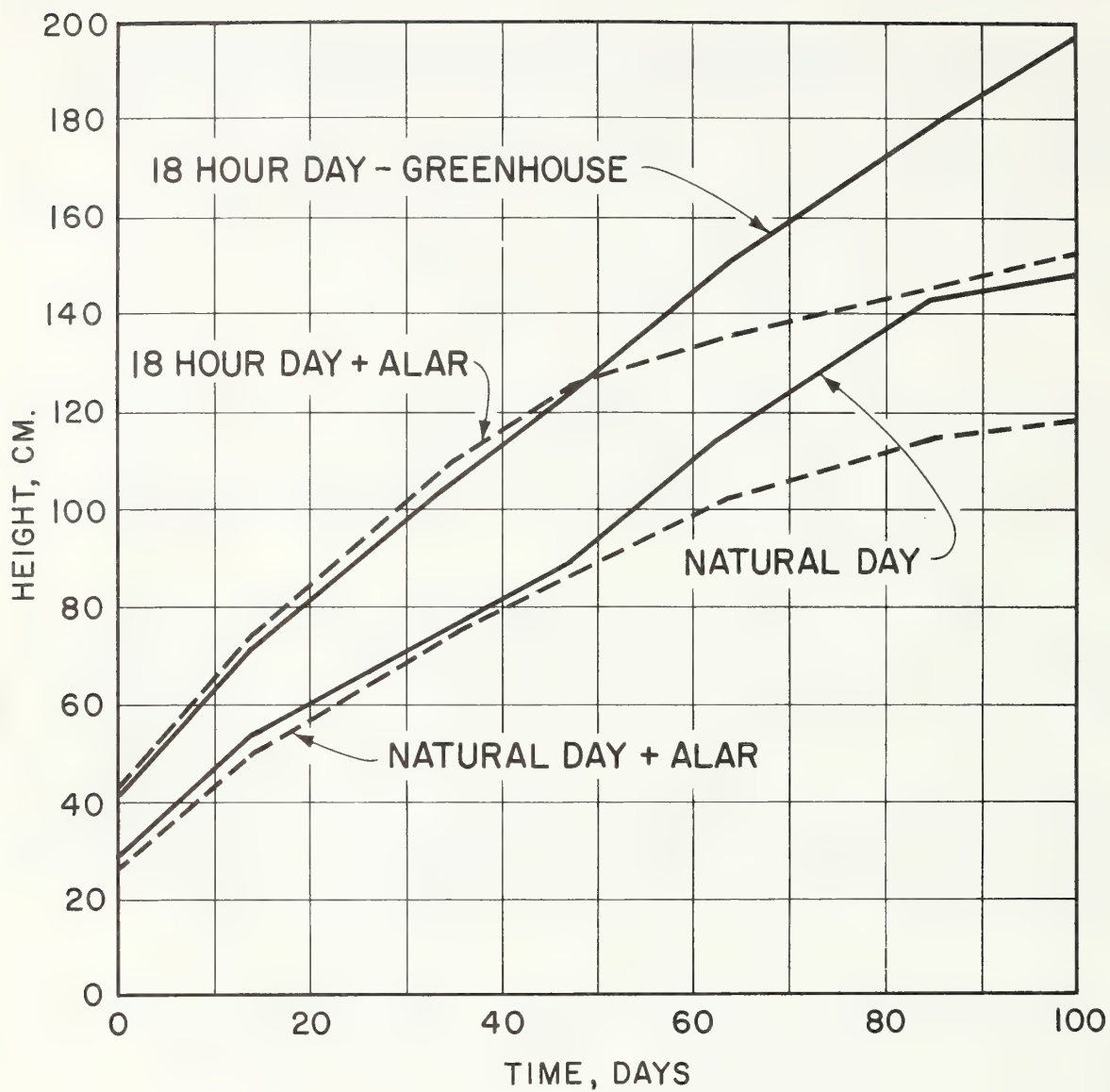


Figure 1.--Cumulative height growth of Prunus serotina as influenced by test treatments.



Figure 2.--Typical plants of three cherry species treated with a soil drench of Alar.

In April 1971, four pots from each family were fitted with covers of hardware cloth and builders felt to exclude rainfall. These trees were observed daily throughout the growing season and watered only when severely wilted in the afternoon; the remaining plants were watered daily. Average plant height at the beginning of the growing season was 100 centimeters for low elevation trees and 82 centimeters for high. One of the following four spray treatments was assigned to each plant in family groups growing under the two moisture regimes: control, 2,000 ppm Alar, 250 ppm Ethrel, and 500 ppm Ethrel. Treatments were begun on May 24 when leaves of most families had attained full expansion and continued at weekly intervals until late June.

Main shoot lengths were measured on April 26, May 25, June 1, and June 18, at which time shoot elongation had stopped. Growth from April 26 through May 25 was 30 to 40 cm and was not influenced by either drought treatment or altitudinal source. Shoot increment (cm) after May 25 for all material is summarized by treatment below:

<u>Soil Moisture</u>	<u>Spray Treatment</u>			
	<u>Control</u>	<u>Alar</u> <u>2000 ppm</u>	<u>Ethrel</u> <u>250 ppm</u>	<u>Ethrel</u> <u>500 ppm</u>
Control	4.6	3.5	1.5	1.3
Drought	5.0	2.5	1.0	0.6

An analysis of variance indicated that growth reductions due to spray treatments were significant (.05 level) and that drought further reduced shoot elongation when coupled with sprays. The lack of drought effect in the control treatment was unexpected, especially in view of the moisture influence in other treatments. In addition to reducing shoot elongation, Ethrel at 500 ppm caused some defoliation on 65 percent of plants by June 8; 15 percent of those sprayed with 250 ppm Ethrel exhibited defoliation. Ethrel-treated plants also exuded a clear gum-like material from the lenticels of shoots. Apical shoots on some of these plants abscised, resulting in lateral shoot development.

In the spring of 1972, all low elevation trees flowered abundantly; no high elevation plants flowered. Flower racemes per tree ranged from 140 to 250, depending upon family. Since size and degree of branching influenced the number of flowers per tree, the number of racemes per shoot terminal was used to evaluate treatment effects. Neither spray treatments nor drought significantly influenced the degree of flowering, which averaged 3.5 racemes/terminal. The control treatment, with an average of 4.4 racemes/terminal, flowered most prolifically. Family means for number of racemes/terminal ranged from 2.3 to 5.0.

Observations in a three-year-old provenance test have confirmed the relationship of altitudinal source to flowering observed in this study. No trees from sources above 640 meters in east Tennessee have flowered at a low elevation site. Thirty-five percent of the trees from sources below 640 meters have flowered at three years, and 30 out of 38 open-pollinated families in this sample contain some flowering trees. It is also notable that while all five low elevation families used in the spray test exhibited some flowering in the field test, in no case did 100 percent of the trees in these five families flower.

DISCUSSION

Evidence to date indicates that the major factor influencing early flowering in southern Appalachian black cherry is genetic variation associated with altitudinal source. Hence, genetic manipulation may be a fruitful approach to development of early flowering in desirable breeding material. Published information for some other deciduous tree species supports this conclusion (Zimmerman, 1972). Because of the generally poor growth and form of low elevation black cherry, caution should be exercised until the breeding value for characteristics other than flowering is evaluated for such cherry. However, populations of early flowering low elevation cherry can provide experimental material for fundamental genetic studies since two or three year generations are possible.

Promotion of early flowering in high altitude selections remains a major problem in improvement efforts. Our data suggest that neither short-term environmental manipulations nor growth retarding chemicals offer immediate promise as practical solutions to this problem. Perhaps the most useful approach to the breeder will be to grow material as rapidly as possible under ideal field conditions. In this regard, fertilization and irrigation may be useful experimental tools.

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SESSION III

CONSERVATION OF FOREST GENE RESOURCES

MODERATOR: R. E. SCHOENIKE

CROP GERMPLASM INTRODUCTION AND PRESERVATION

George A. White and Howard L. Hyland ^{1/}

Abstract--The Agricultural Research Service, U.S. Department of Agriculture, has a systematic program for introducing plant germplasm and providing for its evaluation, use, and preservation. New introductions are obtained mainly through correspondence, planned explorations, and P.L. 480 projects. Incoming materials are inspected, checked for proper nomenclature, documented in published inventories, and distributed. Four Regional Plant Introduction Stations are the prime receivers of the germplasm on a crop priority basis. Seeds are obtainable from working stocks of these stations and the Small Grains Collection. Long-term preservation of seed is the responsibility of the National Seed Storage Laboratory. Plant materials such as cultivars, inbred lines, genetic stocks, and plant introductions are stored under favorable conditions. Agronomic, horticultural, forest, and aesthetic crop seeds are all qualified for storage. There are more than 82,600 accessions in storage.

Additional keywords: Plant Introduction, seed storage, plant germplasm, genetic vulnerability.

There is an increasing worldwide awareness of diminishing crop germplasm, especially in rapidly developing countries. The importance of introducing, using, and preserving crop germplasm in the United States is magnified by the fact that relatively few crops (sunflower and several small fruits) are native and by the vulnerability of some crop cultivars with narrow genetic bases. The bulk of our new germplasm must come from foreign sources. Use of such germplasm is the most practical approach in developing pest resistance, amenability to mechanical harvesting, quality, yield, and other characteristics desirable in crop cultivars.

It seems most appropriate that the Southern Tree Improvement Conference be concerned about the preservation of tree germplasm. Our objective in this paper is to acquaint you with the systematic program of the Agricultural Research Service, U.S. Department of

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Agriculture, for crop germplasm introduction, use, and preservation. Emphasis will be on preservation for future use.

PLANT INTRODUCTION AND FOREIGN EXCHANGE

The Germplasm Resources Laboratory is the focal point for plant introduction. Program specialists assess germplasm needs, determine proper areas for collection, conduct or provide back-up support for explorations, document and distribute new accessions, screen limited groups of germplasm for certain characteristics, and conduct research on potential new crops. Introductions are obtained through correspondence, foreign and domestic explorations, and through special programs such as P.L. 480 projects. Incoming materials are inspected by plant quarantine officials for possible insect and disease pests. This is a highly important safeguard for established economic crops in the U.S. Accessions are also checked for proper scientific name and authority, documented in published inventories (fig. 1), and distributed in accordance with established procedures and priorities.

325175. PRUNUS PERSICA (L.) Batsch Rosaceae. Peach.

From Kenya. Seeds purchased by R. E. Perdue, Jr., Crops Research Division, Plant Industry Station, Beltsville, Maryland. Received Feb. 2, 1968.

Col. No. 9519. From Nairobi market. Originally from farm of Dr. Spears, Limuru, and Mrs. Morson, Kiambu. Purchased Jan. 22, 1968.

325176 and 325177. MALUS SYLVESTRIS Mill. Rosaceae. Apple.

From Canada. Plants presented by the Horticulture Division, Central Experimental Farm, Ottawa. Received Feb. 6, 1968.

325176. 'Ottawa 3'.

325177. 'Ottawa 12'.

325178 to 325526.

From the Union of Soviet Socialist Republics. Seeds collected by Willis H. Skrdla, agricultural explorer, Crops Research Division, Regional Plant Introduction Station, Ames, Iowa. Numbered Feb. 2, 1968.

325178. ACER CAMPESTRE L. Aceraceae. Maple.

Col. No. S-319. Stavropol region. Collective farm near Bekeshevskaya village. Low area near stream. Branches small; bark ridged, similar to *Euonymus* \times *alatus*.

325179. ACONITUM sp. Ranunculaceae.

Col. No. S-206. Stavropol region. Above Teberda village on top of Mt. Hatipara, south slope. Elevation 2,166 m. Seed from several plants.

325180. AGROPYRON CRISTATUM (L.) Gaertn. Gramineae. Crested wheatgrass.

Col. No. S-83. Stavropol region. High ridge on rocky limestone soil, south of Stavropol.

Fig. 1. A partial-page sample from a published plant inventory, illustrating the type of information that is recorded for plant introductions.

There were about 9,300 new accessions in 1972. Those that must be propagated, or placed in post-entry quarantine, go to the Glenn Dale, Md., Plant Introduction Station. These materials are distributed after they have been propagated and/or declared virus-free by plant quarantine specialists.

Numerous requests for U.S. crop cultivars and Plant Introductions are received from other countries. For example, about 35,000 items in 1,100 shipments were sent to 110 countries in 1972. In addition, more than 2,200 cultivars or species were provided under special arrangements to AID missions. These exchanges foster good working relations, contribute to foreign research programs, and open new channels to germplasm needed by U.S. crop specialists.

Requests for germplasm are channeled through Regional Plant Introduction Stations and Regional Technical Committees to our germplasm laboratory. Other government agencies such as FS, SCS, CSRS, and State AES participate in the Regional Technical and the National Coordinating Committees. The private sector works with these groups by making known their germplasm needs. There is no FS representative on the Southern Regional Technical Committee.

USE OF GERMPLASM

Four Regional Plant Introduction Stations are the prime receivers of introduced germplasm. Distribution to these stations is based on established regional crop priorities. These priorities do not always imply that a given crop is more important in one Region than another; it does provide coverage for all crops. New accessions are grown out for increase, general evaluation, and possible screening for insect and disease resistance. Working stocks are available to all cooperators upon request. The Regional Coordinators and state technical representatives make recommendations concerning germplasm needs and coordinate evaluation and use of germplasm within the region or respective state.

The Small Grains Collection at Beltsville has more than 68,000 accessions of wheat, barley, oats, rye, Aegilops, and rice. This is a working-stock collection for domestic and foreign researchers. New introductions are increased, characterized, and added to the collection stocks. Generally, all cereal accessions are grown the first season in detention nurseries to determine freedom from exotic pests.

The Regional Stations and the Small Grains Collection are responsible for providing seed for long-term storage by the National Seed Storage Laboratory, Fort Collins, Colo.

CROP GERMPLASM PRESERVATION

The National Seed Storage Laboratory began operations in 1958, and is responsible for long-term preservation of valuable crop germplasm.

The Laboratory is primarily a storage facility but is also a source of seed when not available elsewhere. Researchers at the Laboratory experiment on seed-storage factors related to longevity.

Let us examine in some detail the operations of this important facility. All types of seeds--agronomic, horticultural, forest, and aesthetic are qualified for storage under minimum standards for quantities and viability. Several categories, including currently released cultivars, inbred lines, obsolescent germplasm, (old cultivars) genetic stocks, Plant Introductions, differential host cultivars, virus-indicator plants, and physiologically useful species, will be accepted. Incoming seed samples are tested for germinability, stored in pint containers in one of eleven cold-storage rooms at 40° F and 32 percent relative humidity, and retested for germinability after 5 years. Lower temperatures can be used if necessary. Crop characteristics of each sample are punched on accession cards. This helps in handling seed requests when certain characteristics are sought. Seed samples can be rejected if germination percentages are below prescribed standards. In the event of seed deterioration, renewal from stored stocks will be accomplished through contract or by cooperating agencies.

There are more than 82,600 accessions presently in storage. These are broken down into broad groups as follows:

Small grains, sorghum, corn	43,865	Ornamental	514
Oilseed, forage, cotton,		Chemurgic (New crops)	339
tobacco, sugar	19,318	Genetic	4,102
Vegetable	14,480	Strategic	11

You will note that there are no tree-seed lots in the listing above. Tree seeds do qualify for storage. In fact, we invite and encourage our colleagues who work with tree germplasm to process new introductions through our documentation system and preserve seeds in the National Seed Storage Laboratory. We will also cooperate in locating foreign sources of tree germplasm in accordance with the present program policy of the USDA Forest Service, Washington, D.C.

For storage, a minimum of 20,000 seeds of tree species would be required. A larger quantity will be necessary if germination test procedures are not known. Germination standards (usually 75 percent or above) have been set for most crops. These standards might well vary for tree seeds because of dormancy factors, short viability of moist temperate tree seeds, etc. Special investigations in storage methods for various tree seeds might be required.

For further information on policies and storage details for the National Seed Storage Laboratory, contact Dr. L. N. Bass, Head NSSL, Ft. Collins, Colo. 80521.

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CONSERVATION OF FOREST GENE RESOURCES: SEED BANKS
AND SELECT TREE REGISTERS

Robert G. Hitt and LeRoy Jones

What program would be complete without its fat facts and frightening figures? I for one, want to insure success for this conference so let me wax wild now for a few minutes with my "fat facts" and "frightening figures."

The 1970 World Directory of Forest Geneticists and Tree Breeders lists about 1140 persons engaged in tree improvement work. Ninety-nine of these were listed under the U.S.A. category. While no claim was made for the list as being complete and totally accurate, it was probably 99 and 44/100% accurate! Of course, there were few listings of any of the non-professional and technician types who are so vital to this endeavor. Many of you are witnesses to this fact in that you were able to come to this meeting because you had a good man or two "back at the ranch" who could keep things running well in your absence.

As a matter of "fat facting", I'd just bet that on the average for each of you here there are at least two others not here who are involved in tree improvement work. This would include all types from laboratory technician to field crews and, yes - even graduate students! Thus, I've estimated a conservative figure of at least 300 man years being devoted to tree improvement work here in the U.S.A. Again, conservatively estimated, that's a 4.5-5 million dollar annual payroll only and if other costs of program operations are added to this, we're probably talking about a total expenditure on tree improvement work in the 10-12 million dollar range. These are truly estimates and may, in fact, actually be "lean facts" that need to be "factually fattened."

The same directory listed tree improvement work in progress with 100 taxons, 45 of which were under some type of improvement in the U.S. This work was being done under 54 different subject categories - and mind you, these were 1969 compilations!

Group Leader, Forest Management, SA-S&PF, U. S. Forest Service, Atlanta, and Program Leader, Cooperative Forestry Division, S&PF, U. S. Forest Service, Washington, D. C.

Well, what does this all say? Simply this - a lot of manpower and money is going into tree improvement work. While it is not as fast moving nor are the results as quickly available as they are in some other types of crop breeding and improvement work, positive and economically rewarding results are emerging. Attending these efforts and rewards is an ever present danger - namely that of the loss of valuable germ plasm. It's true that most tree improvement programs attempt to preserve selected lines through grafting or other vegetative propagation means. Personnel changes and the passing of time combined with the vagaries of natural phenomena, insect and disease losses, etc., all take their often small, but steady toll. I'd venture to say that a number of you here have already lost one or more genotypes which should have been preserved for possible future breeding work.

Two activities which we'd like to discuss here briefly today can contribute significantly to this omnipresent danger - that is, the loss of valuable germ plasm. The first of these is concerned with the preservation of typical seed of selected trees, species, origins, special hybrids or what have you. LeRoy Jones pulled together the presentation on this subject.

The storage of tree seed as a means of conserving germ plasm has received little attention anywhere in the world. The same was true for crop plants until recently. In fact, the valuable germ plasm of many crop plants has been lost over the years. Of the clovers introduced into the United States during the past 70 years, only 2 percent of the original lines are available today. Original parental lines for over 65 percent of the introduced oats have been lost and 90 percent of the soybeans.

Through man's selection and breeding of plants over hundreds of years, certain desirable qualities were often unwittingly sacrificed -- take, for example, the ability to resist a certain disease. The progenitors of many of today's crops were the only sources of these qualities - some are now gone forever.

In the preservation of forest tree germ plasm the situation is not yet as critical. Many species have limited ranges; however, management practices, urbanization, and land use can uproot primitive plant communities all too quickly. What should we do to conserve endangered germ plasm which may contain characteristics that may be valuable at some time in the future?

Tree germ plasm may not be lost as rapidly as agriculture crop plants germ plasm may be, but it may be wise to give more attention to

gene preservation, whether it be through natural areas, live tree banks, seed banks, or a combination of these.

Let us go back to the agriculture crops to review what is being done to preserve the seed of valuable selected cultivars of plants. The Agriculture Research Service opened the National Seed Storage Laboratory in 1958 at Fort Collins, Colorado. The establishment of the Center had the support of various Federal, State, and private agencies throughout the country.

Preservation of germ plasm at the Lab is accomplished through the collection and storage of seed of known value. All agronomic, horticultural, forest, and aesthetic types are qualified for storage, but only seed are stored. There is no charge. Research people may submit obsolete varieties, current varieties, breeding lines, and genetic stocks. Once in the Laboratory, the seed becomes the property of the Federal Government and are available to researchers in the United States when the Lab is the only known source.

Germination tests are run on incoming seeds. They are then placed in one of the eleven cold storage rooms. The crop characteristics of the seed stored are recorded on accession cards. They enable the Lab, through a computer program, to locate seed having certain crop characteristics for which they receive requests.

Periodically over the years, the seed are tested for germination. In the event that deterioration does occur, contracts are made with a seed-producing agency to replenish the stock with seeds obtained from controlled plantings of present stocks. Under the storage conditions at the Lab, regeneration of crop seed is not required sooner than 10 to 20 years after storage.

Tests have established that we could store many kinds of tree seed for much longer periods -- perhaps 2 to 4 times longer. No tree seed are presently stored in the National Seed Storage Lab; however, it is possible to store tree seed under the present setup.

We may want to seriously consider storing seed from some special areas, or seed with special characteristics. For example, the Loblolly pine seed from the Silver Springs, Florida area, seed from trees with special marker genes, or insect or disease resistant materials.

The National Seed Storage Laboratory has a detailed policy statement concerning seed accepted for storage, information required, who can receive seed from storage, objective for storing seed, and treatment

during storage. Storage application forms are provided by the Lab. For further information, or if you have special seed which needs to be stored for possible further use, you may wish to contact the National Seed Storage Laboratory, Agricultural Research Service, Fort Collins, Colorado 80521.

Dr. Louis N. Bass is Head of the Laboratory. (Copies of a Storage Application Blank and the policy statement about the Laboratory are in the Appendices.)

If you think material should be placed in storage, the Southern Forest Tree Improvement Committee may consider a subcommittee to develop guidelines -- in fact, it may even be desirable to have a National Committee for this purpose.

The second kind of activity suggested as a means of helping to preserve valuable germ plasm is that of compiling a regional or even national register of selected forest trees that have been identified and/or used in tree improvement efforts. While the register will not insure preservation of desirable genotypes in any true sense, it can help by making the traits and characteristics of all registrants common knowledge. If plant material is then distributed from these selections for inclusion in a number of breeding programs, the likelihood of a complete loss of the genotype is reduced since through seed or vegetative propagation it would be established in a number of localities. Cross referencing via the system would permit recovery from surviving sources.

A proposal for the compilation of a southwide select tree register is not a new one for the Southern Forest Tree Improvement Committee. The subject was discussed at both the 1955 and 1958 meetings. The discussion in 1958 indicated it was not practical to attempt to draw up a register at that time.

Numerous comments and suggestions followed. Responding to a request by the Southern Forest Tree Improvement Committee in 1963, the U. S. Forest Service, Division of State and Private Forestry, through their Regeneration Branch reinvestigated this need in early 1964. A questionnaire (Appendix C) was sent to all the Southern State Foresters. In addition, industrial organizations, private foundations, and the universities and colleges throughout the south known to have active tree improvement programs were contacted. The purpose of the questionnaire was to determine the desires and needs of all the agencies involved regarding the compilation of a southwide selected tree register.

Sixty-nine (69) questionnaires were distributed. Fifty-nine (59 or nearly 86 percent of the questionnaires were returned. The distribution of the questionnaire was as follows:

- 11 - to State Foresters
- 13 - to Universities and Colleges
- 41 - to industrial and other organizations
- 4 - for informational purposes only

The main question on the form was "Would your organization be interested in and willing to cooperate in the compilation of a southwide inventory or register of selected forest trees being used in tree improvement work? Yes ____ No ____." Qualifications for the "yes" and "no" answers were numerous.

The State Foresters' returns were:

- 11 - questionnaires sent
- 10 - questionnaires returned
 - 6 - "no" votes of which several were qualified
 - 2 - "yes" votes
 - 1 - interested
 - 1 - not sure

The Schools of Forestry voted thus:

- 13 - questionnaires sent
- 13 - questionnaires returned
 - 3 - "no" votes
 - 10 - "Yes" votes
 - 3 - had tree improvement programs
 - 7 - no tree improvement programs

Forty (40) questionnaires were sent to Industrial Organizations. Thirty-three (33) of these were returned. The replies were most accurately tabulated as follows:

Have tree improvement program - want register compiled	5
Have tree improvement program - <u>do not</u> want register compiled	10
Have <u>no</u> tree improvement program - want register compiled	11
Have <u>no</u> tree improvement program - <u>do not</u> want register compiled	7

Considering all returns from all sources, the "do's" don't and the "don'ts" do. Here's what the overall tally showed:

Had tree improvement program - wanted register compiled	6
Had tree improvement programs - <u>did not</u> want a register compiled	16
Had <u>no</u> tree improvement program - wanted a register compiled	21
Had <u>no</u> tree improvement program - <u>did not</u> want a register compiled	11
	<u>54</u>
Had a program - thought register of questionable value	4
Had no program - were only interested	<u>1</u>
Total returns	59

Exactly one-half of the tabulable replies favored the register, one-half opposed it. Of those favoring the register, only 22.2 percent (6 of 27) had active tree improvement programs and could contribute to the register, or to put it another way, over 77 percent of those favoring the register couldn't actually contribute to it. Based on the survey, it seemed inadvisable to undertake compilation of the register at that time.

The response to the question "What additional special entries would you suggest be included?" gave some idea of the problems existing or anticipated as the tree improvement programs developed. Numerous comments suggested that wood properties (tracheid length, cell wall thickness, etc.) be included in register data. Progeny tests and testing were mentioned as was hybridization work. Several respondents suggested the need for more site data relative to the select tree's location.

A report on the survey was presented to the Southern Forest Tree Improvement Executive Committee meeting in June 1964.

And, so here we are - ten years later and coming at you again with this same question - would this organization be interested in and willing to cooperate in the compilation of a southwide (or even a nationwide) inventory or register of selected forest trees being used in tree improvement work? Let me repeat, while the compilation of a register will not fully insure preservation of desirable genotypes in any true sense, it can help by making the traits and characteristics of all registrants common knowledge, assist in their broader propagation and utilization and thus reduce the likelihood of complete loss of genotypes to natural or other causes.

These, Mr. Chairman, are the "fat facts", frightening figures and two questions:

- 1) Wouldn't it be worthwhile to start storing some of our southern forest tree germ plasm via their seed in the National Seed Storage Laboratory at Fort Collins, Colorado?
- 2) How about establishing a Regional or National Select Tree Inventory? Computerization makes this quite possible in today's world.

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE

National Seed Storage Laboratory

Fort Collins, Colorado 8052

STORAGE APPLICATION
Storage Location

Room _____ Rack _____ Drawer _____ Date _____

From _____

Address _____

Kind of Seed _____ Origin _____

Amount submitted _____

Botanical Name _____

Agronomic or Horticultural variety name _____

Synonyms _____

Identification numbers _____

Crop year of seed _____

Is the seed available in commercial channels? _____

Do you plan to maintain this variety of stock? _____ How long? _____

May other research men obtain this seed from you? _____

Can arrangements be made with your administration for the increase of new
stocks in case of depleted stocks or drop in viability? _____

Person and/or agency authorized to enter such increase agreement: _____

Name _____ Position _____

Address _____

SPECIAL NOTICE

The policy under which the Laboratory operates requires documentation.
Special attention should be given to this section.

References to published descriptions: _____

Please enclose copies of the above references.

THE ABOVE INFORMATION IS NEEDED FOR OUR PUNCHED CARD SYSTEM AND SHOULD
BE SENT WITH THE SEED.

APPENDIX B

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE

NATIONAL SEED STORAGE LABORATORY
Colorado State University Campus
Fort Collins, Colorado 80521

POLICY STATEMENT

1. The Laboratory is a Federal facility and all seed accepted for storage becomes Federal property.
2. Only seed will be accepted for storage.
3. Valuable seed stocks will be accepted by the Laboratory from Federal and State institutions, commercial seed interests, and private individuals. The basic criterion for acceptance is its potential use in plant breeding and genetic studies or fundamental biology. Information as to history and genetic composition and complexity is required for the retrieval of certain genotypes.
4. Any bona fide research worker of the United States, its territories and possessions, may receive seed from collections stored at the Laboratory subject to the restrictions in Item 6. However, seed will not be provided by the Laboratory if available commercially or in working stocks of research agencies. The Laboratory will suggest sources of supply.
5. The Laboratory will have no responsibility in relation to commitments with foreign countries. All requests from foreign sources will be channeled through the proper administrative office, where decisions in relation to foreign countries will be made.
6. Both public and private donors of specific lots of valuable seed stocks or seed of new varieties, who wish to do so, may retain for a period not to exceed five years the exclusive right to withdraw or permit withdrawal of portions of such seed provided the optional restriction is clearly indicated at the time the seed lot or sample is deposited. No seed collection may be withdrawn in its entirety. After such time limit has expired, and on seed lots or samples deposited without this restriction, all seed deposited in the Laboratory shall be available to any bona fide research worker, whether public or private, of the United States, its territories or possessions.
7. The Laboratory will not hold bulk supplies or seasonal stocks; it is not a warehouse or seed distributing center. Rather, it is a germ plasm bank for valuable stocks to be held over the years for the use of research workers when needed.

8. The Laboratory will issue periodic inventories of the stocks held in storage to inform research workers of material available.
9. Only clean seed of reasonably high germination is acceptable for storage. If seed of low viability (below 60-65% germination) is received, it will be held on a tentative basis until the donor is able to provide replacement seed of higher viability (75% germination or better).
10. No charge will be made by the Laboratory for the service of furnishing seed. The Laboratory will use every care in keeping good records, but it is not responsible for errors which may occur in the original documentation. The varietal name supplied by the donor will be accepted by the Laboratory.
11. When seed has been accepted officially, the Laboratory will be responsible for the increase of stocks if, during storage, viability drops to a point where there is danger of loss of the accession or stocks have become depleted as a result of seed distribution.
12. The Laboratory will not assume responsibility for replenishment of stocks if the accessions received are subminimal in quantity or viability. However, if obsolete varieties are received not meeting the preceding acceptable standards, the Head of the Laboratory in consultation with the appropriate specialists in the Agricultural Research Service may make arrangements for increases.
13. The principal objective of the Laboratory is long-time holding of valuable seed. Research projects will be carried on at the Laboratory related to the Laboratory's objective, i.e., physiological and pathological problems in seed viability and longevity.
14. The acceptance of seed of a commercial variety by the Laboratory shall not be considered in any way a Federal endorsement as to the value of the variety.

In addition to the above policy, recommendations have been made as to what constitutes "valuable seed." It is recognized that such a definition will vary greatly depending upon the significance attached to the present commercial value of the crop involved and the individual research worker's evaluation whether he be a geneticist, horticulturist, agronomist or pathologist. However, the following categories of crop seed will be accepted by the Laboratory:

New Varieties:

All newly released varieties, whether of private, public or commercial origin, including reselections from varieties continuing in current use.

Current Varieties:

Varieties currently in use and under registration by respective crop group organizations, or otherwise documented as to specific origin and distinguishing characteristics. In this group would be included those varieties approaching obsolescence which have been superseded by new or currently popular varieties.

Open-pollinated Varieties:

Stocks representing earlier varieties or types of specific crops which have been or will be replaced in the commercial field by hybrids.

Inbred Lines:

Parental lines of known genetic composition widely used in combination for hybrid production.

Obsolescent Germ Plasm:

Samples representing holdover material from earlier research programs and of no immediate interest.

GENETIC STOCKS:

Includes materials of academic and genetic interests such as marker genes, mutants, translocations, monosomics, trisomics, and other chromosome aberrations. Replenishment of such stocks, if in a heterozygous state, will remain the obligation of the donor. With the latter type of stocks the Laboratory serves only as an insurance against loss.

Plant Introductions:

From Regional and Federal Introduction Stations or other agencies as seed is increased beyond "working stocks."

Differential Host Varieties:

Used or being used as differential hosts for differentiating pathogenic races.

Virus Indicator Plants:

Used in indexing plant viruses.

Physiologically Useful Species:

Used in physiological studies or physiological assays.

All inquiries as to minimum quantities of seed required for specific crops, documentation, condition or quality and other routine information should be addressed to the USDA, National Seed Storage Laboratory, Colorado State University Campus, Fort Collins, Colorado 80521.

APPENDIX C

QUESTIONNAIRE ON A PROPOSED SOUTHWIDE SELECT TREE REGISTER

1. Would your organization be interested in and willing to cooperate in the compilation of a southwide inventory or register of selected forest trees being used in tree improvement work?

Yes _____ No _____

2. How or for what purposes would your organization use the register?*

(a) For information regarding possible exchanges of plant material _____

(b) For information regarding possible cooperative testing, breeding, etc. _____

(c) Other purposes, including _____

3. Individual tree entries would include all the standard information, such as height, diameter, location, specific gravity, grader's name, etc. What additional special entries would you suggest be included?*

*Answers to these questions will help determine the type of data recording system to be used.

4. Should an informational meeting be held (a) prior to _____, (b) during the processing of _____, or (c) upon completion of the final register _____? OR should we skip the meeting, get the job done, and report on it at a coming southwide tree improvement meeting _____?
5. Does your organization need or know of any other forest tree improvement services which the U. S. Forest Service, because of their regional representations, should render or make available? If so, please list briefly _____

6. Would you be interested in receiving an informal Tree Improvement Newsletter from time to time regarding local, regional, and national tree improvement items? Yes _____ No _____

REGISTRATION AND RELEASE OF IMPROVED FOREST TREE MATERIALS

R. E. Schoenike^{1/}

Abstract.--Improved forest tree materials are now being produced by cooperatives, state and Federal agencies, and private breeders. Most of this material has not been formally released in a manner that agronomists and horticulturists have been doing for many years. This paper explores some of the policies that our colleagues in these fields have developed, and also looks at the machinery that has been set up to implement them. A number of suggestions are offered whereby improved forest materials can be registered and, eventually, be released.

Additional keywords: Cultivar, Federal Seed Act, Plant Patent Act, Plant Variety Protection Act.

Forest tree improvement programs are now reaching a stage where improved germplasm is being made available to growers by both public and private agencies. Because the public has an important stake in tomorrow's forests, there should be provided reliable means whereby the types of trees grown can be identified and evaluated. As long as wild plants were used for reforestation, it made little difference what parentage was involved, and there was no need to identify any plant except as to species. But today, what do we have? In loblolly and slash pines, our most highly-bred tree species, a partial summary of the types of seed stocks available for reforestation includes: (1) geographic provenances (2) seed production area material, (3) open-pollinated seed orchard stock - general or by family lines, (4) control-pollinated seed orchard stock, general or by families, (5) disease-resistant stock, (6) special production stock such as high gum-yielding strains, high and/or low specific gravity stock, etc., (7) interspecific hybrids, (8) open-pollinated natural hybrids, (9) inbreds, and, finally, (10) wild stock. In fact, the papers presented at this conference are proof of the great range of materials that are being or that soon will be produced. In a few other species such as cottonwood there is one additional category: (11) clonal lines. How do we identify all this material? Presumably, each agency keeps its own records and in the cooperatives, there is some sort of general control. Should there not, however, be a central registration agency within the field of forestry that will keep records of the type of stock that is produced, and to which any qualified person can go to find out matters of parentage, performance, and adaptability? In attempting to answer that question let us see what our colleagues in Agronomy and Horticulture, with their long experience in developing improved crop varieties, have done about this matter.

Related topics that fall into consideration here include the following: (1) Federal and State seed laws, (2) seed certification, (3) release of new germplasm, (4) registration of cultivated materials, (5) maintenance and propagation of basic stocks, (6) plant patents and variety protection; and (7) crop germplasm preservation. Primary emphasis in this paper will be directed toward items (3) and (4) although other topics will be referred to as needed.

The methods followed by public-agency breeders are standardized throughout the country and vary little from state to state. The basic document (dated June 26, 1972,) is entitled 'A Statement of Responsibilities and Policies Relating to the Development, Release, and Multiplication of Publicly Developed Varieties

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of Seed Propagated Crops.' (11) It was prepared by the Experiment Station Committee on Organization and Policy (ESCOP) and the ARS and SCS, agencies of the U. S. Department of Agriculture. The policy is limited to seed stocks of field and horticultural crops and does not cover material that is propagated vegetatively. The policy statement covers such topics as breeding to develop superior varieties, testing and evaluating experimental varieties, release and registration, maintenance and increase of seed stocks, and publicity policy on new releases. A few excerpts from this publication relative to release and registration are quoted here:

"Decisions on the release of new varieties should be made for each state by the appropriate agricultural agency of that state. It is recommended that in each state there be a policy committee or board of review charged with the responsibility of reviewing the proposal for the release of a new variety."2/

"A variety should not be released unless it is distinctly superior to existing varieties in one or more characteristics important for the crop, or it is superior in overall performance in areas where adopted and is at least satisfactory in other major requirements. A single major production hazard which a new variety can overcome, e.g., a highly destructive disease, may become the overriding consideration in releasing a variety."3/

"A new variety should be given a permanent designation before it is released . . . Brevity in designation is desirable. When this designation is a name, one short word is preferable; two short words are, however, acceptable. Meaningful number designations . . . are also acceptable . . . The International Code of Nomenclature for Cultivated Plants provides guides for the naming of varieties. It is recommended that this source be consulted with respect to variety4/ names."5/

"Under no circumstances should a variety be distributed under more than one name nor should the same name be used more than once in a given crop. Similar names should also be avoided . . . Once established, a legitimate varietal name should not be changed . . . "6/

"New varieties of crops should be registered. Information for the registration or listing of varieties should be submitted promptly following registration of the variety with the Crop Science Society of America (CSSA) or the listing of the variety with the American Society for Horticultural Science (ASHA)."7/

At the local level each Agricultural Experiment Station has a crop variety and release committee which meets one or more times yearly to consider the release of new varieties. Upon its recommendation the Experiment Station Director then approves the release. Where other cooperating agencies are involved such as

2/ Section 5, Part (a).

3/ Section 6.

4/ The word 'cultivar' is considered synonymous with 'variety.'

5/ Section 7, Part (a)

6/ Section 7, Part (b)

7/ Section 7, Part (c)

ARS, the release is made jointly. The local committee also makes policy relating to crop variety recommendations. This may vary from state to state, but usually will include representatives of the seed industry, various state organizations, the Extension Service and the Agricultural Experiment Station.

The breeder's function in this procedure is to submit a proposal for release of an improved variety or strain when sufficient performance data and other records indicate that it has merit. Ordinarily the breeder maintains breeder seed until it is turned over to a designated authority, often a foundation seed association, who increases it as needed for the production of foundation seed. Foundation seed is then used for commercial production. All classes of seed so produced come under the regulation of Federal and state seed laws and certification procedures are required.

Most private breeders are attached to the large seed companies. The general procedure in releasing new varieties is to grow breeder seed for several generations in order to build up stock, then build up foundation seed by contract to growers. Before being sold this seed goes through seed certification procedures. Breeders or their companies may apply for Certificates of Protection under the Plant Variety Protection Act. This Act allows them exclusive rights to sell or market seed under a protected variety name. Release notices are sent out through advertising by the seed company and by announcements through the National Council of Commercial Plant Breeders (NCCPB). Private breeders may also register their seed with the Crop Science Society of America (see below).

Let us turn next to the policies and procedures of the two major professional societies in registering and listing releases.

The Crop Science Society of America has a formal mechanism for registration of crop cultivars, parental lines, and elite germplasm. This is outlined in the Nov.-Dec. 1971 issue of Crop Science (8). The procedure was developed by the Variety Registration Committee of the Society. Crops that may be registered include cereal grains, cotton, forage-, range-, and turf-grasses, legumes, oilseed crops, sugarbeets, sugarcane, and tobacco. Material to be registered must ordinarily have been released after January 1, 1960. Registration is accomplished by submitting an appropriate form obtained from the Subcommittee Chairman responsible for a particular crop and is accompanied by a registration article. The latter is published in Crop Science. The following information concerns the registration article:

"Registration articles must be concise and include the following:

- a. Name of identification assigned at time of release.
- b. Botanical name, including the authors of the binomials.
- c. Experimental number or designation used during development.
- d. Names of agencies and organizations involved in the development and evaluation of the plant.
- e. A brief description including distinguishing characteristics and breeding procedures.
- f. Probable region of adaptation, generations of seed increase, and area of seed production, where applicable, for cultivars.

g. The institution or organization that will maintain basic stocks of these materials.

h. Any limitation on the availability of parental lines or germ plasm."^{8/}

Registration numbers are assigned by the Chairman of the Registration Committee. Numbers are assigned serially, and are grouped into three categories, i.e.,

For cultivars - no prefix before the number;
For parental lines - number is prefixed by PL;
For elite germplasm - number is prefixed by GP.

A reference file for all registered material is maintained by the CSSA.

Guidelines for registering parental lines include their demonstrated merit in applied breeding programs, their official release, and a description or citation to original source for the material from which they were derived.

Elite germplasm is any material that is improved by breeding procedures but does not fall into the category of variety (cultivar), or parental line. It may include clonal (non-seed propagated) material, composite crosses, or mixtures of germplasm.

Certificates are issued for each cultivar registered, but not for parental lines or germplasm.

In my opinion the CSSA has progressed the farthest on the question of registration than any other group, and its policies and procedures could prove valuable to foresters when the time comes to set up registration for improved forest tree materials.

The American Society for Horticultural Science (ASHS) does not register plant materials directly but does have vegetable varieties, fruit and nut varieties, and various horticultural crops and plants listed in the journal HortScience. There have been various ways of listing these new varieties, but until recently most of them were very brief - not much more than announcement of new plants, their names, and a few outstanding characteristics. A decision made this past year was to standardize the form for announcing new cultivars, and to publish a more detailed description of them. The first of these new cultivar descriptions was published in HortScience in its January 1973 issue (2). The information published in HortScience follows a certain format, e.g.

"1. Title (e.g., 'Sureglow' Strawberry).

2. Author(s).

3. Text.

- a) identification (to include species, purpose, region of adaptation);
- b) origin (parentage, development, breeders responsible);
- c) description (plant, flower, fruit) - photos may be included;
- d) outstanding characteristics and uses (performance results, pest resistance);
- e) availability (sources of seed or clonal materials).

The three major commodity groups in ASHS handle the announcements separately. Information on new vegetable varieties is coordinated with the American Seed Trade Association (ASTA) and is standardized on a card form that includes the following information (5):

- Name of variety and (where needed) experimental designation number;
- Originator's name and address;
- Breeding category (F hybrid, O-P line, etc.) and parentage;
- Distinguishing and outstanding characteristics;
- Disease resistant features;
- Regional adaptation;
- Reference to published description;
- Date of release.

The form is available from ASTA or ASHS.

A descriptive list of all vegetable varieties introduced between 1936 and 1968 has been published jointly by the two societies.

For listing its varieties of new fruits and nuts, the ASHS has a two page card form which is called a register. The basic data called for on the card consists of (6):

- Name of variety, species, and synonyms;
- Originator's name and address;
- Patent number, date, and assignment of patent;
- Date variety was introduced commercially;
- Place or origin;
- Parentage and breeding category;
- Description of fruit or nut including refining and harvesting date;
- Hardiness, vigor, disease resistance;
- Size and shape of plant;
- Record of productivity.

The card form is available from ASHS.

The University of California Press has recently published a Register of New Fruit and Nut Varieties, describing all important new commercial varieties introduced between 1920 and 1970.

Certain federal laws apply to propagated plant material. The Federal Seed Act of 1939 gives authority to Seed Certification Associations in setting up and enforcing standards for various classes of seed and sets standards for purity, germination, etc. The Plant Patent Act of 1930, amended 1954 (21), allows a breeder or grower to obtain exclusive rights to the propagation and sale of asexually produced plants (including most horticultural clones and a few crops such as potatoes). The Plant Variety Protection Act of 1970 (22) allows breeders and growers to obtain rights to the propagation and sale of sexually produced plants (by seed). This law went into effect on November 27, 1972 (18). Applications for variety protection were accepted as of January 1, 1971 and by December 31, 1972, the Plant Variety Protection Office had received 303 applications. Thus it appears that breeder-growers are taking advantage of the opportunities afforded under the Act, and that it is filling a real need. Applications received are printed in the official Journal of the Plant Variety Protection Office (19). The Protection Office is currently developing 'objective descriptions of varieties' for the plants that can be protected under the Act, but it is expected that it will take several years before the work is completed. After certificates have been issued (none as of March 31, 1973), the Registry of protected varieties will begin. These will also be published in the Official Journal.

A second group of societies and agencies is concerned with the registration of cultivars of ornamental plants - those that are asexually propagated. The number of names of cultivated plants in the literature run into the tens of thousands, and it has been no easy task to catalog them, much less to identify them.

Registration for ornamental plants has been urged by several International Congresses of Botany and Horticulture and by the International Union of Biological Sciences. This last association is now responsible for the International Code of Nomenclature for Cultivated Plants, first published in 1952. The latest edition (4th) dates from 1969 (15).

A recent article by DeWolf (10) of the Arnold Arboretum points up several serious problems in the naming and identification of plants. The International Code has stressed that the basis of varietal nomenclature must be a series of Registration Lists.

"Such lists, when completed, will form the basis for future registration of distinctive cultivated plants under equally distinctive names. The List should enable one to determine the validity of existing names which are to be regarded as cultivar names and clearly indicate names which have been used previously within a genus and therefore may not be used again. Only a few such lists exist." (10)

The oldest list in current use is that for orchids which was begun in 1896.

The code has strongly urged that Official Registration Authorities be appointed to register new cultivars in certain plant groups. The authorities are, commonly, professional or quasi-professional plant societies specializing in particular plants (e.g., the American Iris Society, Holly Society of America, Royal Horticultural Society, etc.). Approximately 40 plant groups (mostly individual genera, but in some cases, botanical families, and miscellaneous collections, are now assigned to 22 International Registration Authorities (4). Reasonably complete lists of recognized cultivars are available for orchids, tulips, daffodils, hemerocallis, rhododendron, azaleas, camellias, hollies, dahlias, iris, gladiolus, and dwarf conifers. The Arnold Arboretum with extensive

experience in compiling lists has been appointed as Registrar of eleven woody genera. It also publishes new cultivars of miscellaneous woody genera for which no authority has been designated. There is one forestry organization in the group of International Registration Authorities. It is the International Poplar Commission in Rome and its assignment is to prepare a list of forestry cultivars in the genus Populus (poplar).

Cultivars registered by the Arnold Arboretum have been published in Arnoldia since 1960. The most recent list of 21 cultivars was published in the Arboretum and Botanical Garden Bulletin for April 1973 (13).

This has been a brief survey of the fields of registration and release as it applies to improved field crops, fruits, and ornamentals. What insight does this give us in application to improved forest trees? I would like to suggest the following:

First: to recognize that in considering improved forest trees we are dealing with a domesticated crop that is mass-produced-and-harvested just as is any agricultural or horticultural crop. (The acreage devoted to such crops will of necessity be restricted because this is a single use of forest land and there are many social and ecological demands upon forests where single uses cannot apply.)

Second: to recognize that the public has a great stake in our future forests and are entitled to know what kinds of trees (pedigreed or otherwise) are being planted.

Third: to recognize that public laws dealing with the seed trade can, and in all probability will, apply to forest tree seeds as to agricultural seeds. In fact, in some states, seed certification laws have already been established to cover tree seeds.

Fourth: to recognize that International tree seed exchange requires a careful documentation of seed source origins and pedigrees, and that the demands for such seed exchange are growing.

Fifth: to recognize the rights of breeders and developers in protecting their improved varieties of forest trees and to realize a profit from them.

And finally: to recognize that progress in forest tree improvements require ready and open cooperation among all agencies and individuals working in the field.

For these reasons, I believe that first steps should be taken by our profession to provide a means whereby improved forest tree varieties can be officially registered. Paralleling the efforts of the Crop Science Society of America which has its Crops Registration Committee, the Society of American Foresters, through its Tree Genetics and Improvement Working group, could establish a similar committee. The first duty of such a committee would be to ascertain the real need for and interest in such a registry. Later, it could function to establish policies and procedures and suggest a time when they could be implemented.

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ESTABLISHMENT OF THE
UNITED STATES FOREST TREE SEED CENTER

James L. McConnell^{1/}

Abstract.--The U.S. Forest Service, in cooperation with state forestry agencies, universities, and private forest industries in the United States, has established the U.S. Forest Tree Seed Center at Macon, Georgia.

The primary purpose of the Seed Center is to furnish small lots of tree seed for species introducing trials, provenance research, tree breeding, and similar purposes to forest researchers outside the United States.

Any organization or company receiving a request from a foreign researcher can send it to the U.S. Forest Tree Seed Center, where the request will be evaluated. If the request qualifies under the established policies, the requestor is sent inventories and price lists. The Center handles all visas, plant quarantine inspections and foreign shipping arrangements for the requested seed.

Additional keywords: Seeds, foreign forestry, import, export.

Since January 1972, experimental lots of forest tree seed from the United States have been shipped to such exotic places as Scotland, Peru, Nepal, Madagascar, Kenya, Japan, Haiti, Gabon, France, England, Ecuador, Brazil, Australia, Argentina, Iceland, Korea, New Zealand, Romania, Turkey and Yugoslavia. These shipments were handled by the Eastern Tree Seed Laboratory in Macon, Georgia as part of a new program called the United States Forest Tree Seed Center.

The need for a centralized seed center had been apparent for many years prior to January 1972. Until then, the U.S. Forest Service handled most requests through its Division of Timber Management Research in Washington, D.C. In addition to the requests handled by the Washington office, hundreds of requests for forest tree seed were submitted to Forest Service field units and to various universities, forest industries, and state forestry agencies. This led to duplication of effort in many cases and unnecessary interruption of work in agencies not equipped to provide such services.

Too, the demand for seed of indigenous United States forest tree species has increased each year. The increasing use of wood and wood products has stimulated forestation efforts throughout the world, which in turn has accelerated tree improvement and forest genetics research. This has resulted in a growing demand for reproductive materials, especially seeds from the United States by foresters in foreign lands. Thus, the U.S. Forest Tree Seed Center was established for three reasons: (1) to facilitate handling the increasing demand for seed; (2) to overcome duplication of effort; and (3) to combine seed handling services at one location.

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The primary purpose of the Seed Center is to furnish small lots of tree seed for species introduction trials, provenance research, tree breeding, and similar purposes to forest researchers outside the United States. Seeds are available to both public and private agencies but are intended for experimental use only, not for commercial purposes. Domestic requests for seed are not honored or supplied from seed stocks of the U.S. Forest Tree Seed Center. It is not intended that seed furnished under this program compete in any way with commercial seed sales. When requests in excess of prescribed limits are received, they are returned to the requestor with recommendations for possible sources of the seed from reliable commercial seed dealers. Approximately one-fourth of the requests fall into this category.

Initially, the Forest Tree Seed Center is furnishing seed and handling collections for all requested tree species east of and including the Great Plains. As personnel and funds become available, however, the Center will handle requests for seed of all U.S. tree species. At present, primary emphasis is on the major southern pine species (Pinus echinata, P. elliottii, P. palustris, and P. taeda); but the inventory of seed now on hand contains seed from over 50 coniferous species and several hardwood species. As requests are received for other coniferous species, collections will be made and representative amounts added to the Center's seed stock for use in meeting current and future requests. Requests for hardwoods, including central and northern species, will be honored as quickly as seed can be obtained. Again, representative amounts will be collected and stored, if feasible, for use in filling future requests.

The Center has cooperative agreements with many forest industries, universities and state organizations in the southern United States. When a request for seed not in the inventory is received, the Center determines which field unit might be able to fill the request. A request is then made to that field unit to collect the seed for shipment overseas. Cooperation for collections of seed by various field units has been excellent. Through this cooperation, the Center has been able to supply such relatively uncommon species as clonally identified Livingston Parish Loblolly for South Africa, Moneymaker variety pecan for Bujumbura, Africa, clonally identified slash low gum yielders for Brazil, select cottonwood cuttings for Korea, individual tree collections for sycamore for France and tung oil seed for Liberia.

A service charge for seed from the U.S. Forest Tree Seed Center is levied to cover the costs of processing requests for seed, and administering the program. The scale of charges is as follows:

1. Seed orchard seed without clonal identification
(1,000 seed maximum).....\$20.00 (U.S.)
2. Seed orchard seed with clonal identification
(100 seed maximum).....\$20.00 (U.S.)
3. All others (except special collections)
Minimum: 500 - 2,500 seed.....\$ 5.00 (U.S.)
2,501 - 5,000 seed.....\$10.00 (U.S.)
5,001 - 7,500 seed.....\$15.00 (U.S.)
7,501 -10,000 seed.....\$20.00 (U.S.)

4. Special collections - based on actual costs. The requestor will be given a price quotation for approval before the collection is made.

5. Requests for special collections outside those normally stocked by the Seed Center will be arranged when possible, with actual costs to be charged to the requesting foreign agency or organization.

6. Shipping charges, other than International Mail, will be paid by the consignee. Shipments over four pounds (2.0 Kg.) must be shipped air freight, postpaid or collect.

The scale of charges for cottonwood (Populus deltoides) cuttings is as follows:

1. Select clones as identified through published descriptive data. Rooting ability generally known. \$1.00 each cutting (a cutting can vary in length from 12" to 22"). Limit 25 cuttings each clone.

2. Un-identified or run-of-the bar cuttings (source identified). Rooting ability not known. \$.50 each cutting. Limit 100 cuttings.

3. Un-identified or run-of-the bar cuttings (source not identified). Rooting ability not known. \$.50 each cutting. Limit 100 cuttings.

Additional requirements for cottonwood:

1. Shipment from the U.S. will be between December 15 and March 1.

2. All cuttings will be shipped air freight. Freight charges to be paid by the consignee.

There are times when the requestor is unable to pay for the seed due to lack of foreign exchange or unavailability of any funds whatsoever. If the request is legitimate, the Center Director may in such cases use his discretion to receive seed of foreign tree species as "payment in kind", or make whatever other arrangements are feasible, including waiving all charges as a last resort in special cases.

In addition to furnishing tree seed to foreign researchers, the Center has been able to advise forestry organizations on regulations and procedures for importing and exporting tree seed. Also, the Center has been able to assist the Southeastern Forest Experiment Station in a seed exchange project with Australia. In this instance, import permits were secured for Eucalyptus seed entering the United States.

The Center has developed an excellent working relationship with the Atlanta office of the U.S.D.A.'s Animal and Plant Health Service, Plant Protection and Quarantine Program. This has made it possible for us to offer a continuing inspection and certification program to assist other organizations in importing and exporting seed and other reproductive material.

Any organization or company receiving a request from a foreign researcher can send it to the U.S. Forest Tree Seed Center, where the request will be evaluated. If the request qualifies under established policies, the requestor will be sent inventories and price lists. The Center will handle all visas, import permits, certificates of origin, plant quarantine inspections, pro forma

documents, foreign shipping arrangements, and other domestic or foreign requirements for the requested seed. In most cases, seed is shipped via International Air Mail. Packages over four pounds must be shipped via Air Freight. The requestor pays all shipping charges.

Further information, including a current inventory of seed available, may be obtained by writing:

Director, United States Forest Tree Seed Center
U.S. Forest Service
P.O. Box 819
Macon, Georgia 31202 U.S.A.

SESSION IV

ADVANCES IN HARDWOOD TREE IMPROVEMENT

MODERATOR: K. A. TAFT

ECONOMICS OF HARDWOOD PLANTATIONS

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ABSTRACT

The industrial demand for hardwoods is steadily increasing, and supplies of natural hardwoods have become critically short in some areas. Few commercial hardwood plantations other than cottonwood have been established due to uncertainty concerning establishment techniques, growth rates, and economical aspects. The author collected data from over 70 older hardwood plantations and constructed yield equations for sycamore, yellow-poplar, and sweetgum. The data indicate that sycamore and yellow-poplar plantations are economically feasible when stumpage prices approach \$10.00 per cord. Optimum rotations are short. Minimum requirements for economically successful hardwood plantations appear to be: Proper site choice, large, healthy seedlings, adequate site preparation and competition control, and in most cases, addition of nutrients.

Keywords: Hardwood plantations, economics

INTRODUCTION

Commercial interest in hardwood plantations has increased in recent years due to localized shortages of suitable hardwood raw material. Although the total volume of natural hardwood in the South increased slightly in the past decade (Sternitzke and Christopher, 1973), many industrial consumers must now pay high stumpage prices for local hardwoods, or pay high transportation fees to import cheap stumpage.

Even companies owning reserves of natural hardwoods relatively close to the mill encounter production and supply problems. A survey initiated by the N. C. State Cooperative Hardwood Research Program in 1969 of the very best natural stands throughout the South indicated that the best forest site type was producing only 80 cubic feet per acre per year, and the average growth across all forest site types was 60 cubic feet per acre per year. Since these data came from the best stands, average annual production would be considerably lower than 60 cubic feet per acre because most stands have been high-graded and are in poor silvicultural condition. These facts suggest the following questions:

1. What growth rates can be expected of hardwood plantations?
2. How can hardwood plantations be most effectively established?
3. What raw material prices are required to make the growing of hardwoods economical?

With these questions in mind, the author attempted in 1971-72 to locate all successfully established hardwood plantations, except those of cottonwood, in the South.

GENERAL CONSIDERATIONS

While nearly every plantation surveyed occurred on a slightly different soil, the soils can be broadly grouped as follows:¹

- Group 1. Good for agriculture. Presence of well-drained, friable topsoil, having sufficient depth and moisture to support a good crop of soybeans.
- Group 2. Adequate for agriculture. Compared to above, the soil is more limiting because one or more of the following conditions prevail. It is shallow, heavy-textured, sandy or gravelly, with limited nutrient and moisture-holding capacity. Some of these soils are still excellent for pine but marginal for soybeans.
- Group 3. Poor for agriculture. Little topsoil, and the texture of the subsoil is tight clay or sand. These soils can support a fair crop of pines but would not economically support soybeans.

Examination of the plantation data indicates that extreme caution must be used in making comparisons among species because of the confounding effect of soils and associated factors. The principal species found growing in plantations were sycamore, sweetgum and yellow-poplar. The natural occurrence of sycamore is along stream bottoms on fertile, well-drained alluvial soils. Sweetgum occurs naturally across a relatively wide range of sites, from the stream bottoms where its associates are sycamore and other bottom-land species, to the drier and infertile hilltops where the oaks, hickories, and pines predominate. Yellow-poplar is usually found on relatively fertile, friable, well-drained, moist soils, but there are many exceptions.

Most sycamore plantations were found on Group 1 soils. Their absence from Group 2 and 3 soils probably indicates that they did not develop into a viable stand, even if planted there. Most yellow-poplar plantations were on Group 2 soils. This species also would not survive and grow if planted on Group 3 soils, which have serious moisture and fertility deficiencies. Nearly all sweetgum plantings were on Group 3 soils. Perhaps because sweetgum has traditionally been scorned by most foresters, it was not generally planted on the best soils. The fact that it exists as a measurable entity

¹Because of the capability of good agricultural lands to grow good stands of hardwoods, site quality was judged by the capacity of the soil to produce an agricultural crop. The author was able to draw on his farming experience and the extensive opportunities he has had to observe both natural and planted hardwood stands. Variables considered in assessing land quality were soil depth, texture, topography, and understory indicator plants.

on the relatively adverse sites indicates the degree of adversity under which the species will survive and grow.

PLANTATION ESTABLISHMENT

The successful plantations sampled in the current survey were growing either on old fields or they had been cultivated to assure establishment. Plantations on old fields do not have the sprout competition that occurs on most cleared forest sites but, even so, the growth of planted trees on some old fields is poor, although survival is generally good. The poor growth is suspected of being attributable to hardpans, or plowpans, which often form in tilled soils and to deficient nutrient levels.

On any site where vines such as honeysuckle, morning glory, smilax, rattan, kudzu, or others exist, competition control is absolutely necessary. Plantings that survived well initially have been observed after several years with nearly every stem tightly wrapped and many badly damaged or killed by girdling or by the weight of the vines. The few trees that out-grow the vines are not likely to compensate for the majority that are deformed or lost.

The many herbicides tested for control of competition in hardwood stands have given inconsistent results to date. The difficulty of predicting the future vegetation on a forest site makes the successful use of preemergence chemicals difficult, and postemergence chemicals generally damage or kill the broad-leaved hardwoods if the application is sufficient to control the competition.

Only partial control of competition in hardwood plantings has been advocated in some cases. One method of attaining this is to plant the seedlings on beds or ridges to provide a temporary cultivation effect and to temporarily control competing vegetation. On some sites this procedure has been initially successful in obtaining adequate survival and growth. On other sites, competition from grasses and weeds has doomed the plantation to failure.

Except on sites where flooding or other factors hinder competing vegetation, cultivation for hardwood establishment appears essential. There is evidence that fertilization in the absence of cultivation may be detrimental due to the stimulation of grasses and weeds. When competition is controlled, fertilization, except on Group 1 soils, appears beneficial although profitability remains a question.

Basic to the successful planting of any species is the need to have a viable seedling. Pine seedlings are produced in nurseries by the millions with such routine success that many nurserymen have assumed that hardwoods can be produced with identical techniques. However, there are many basic differences between the two species complexes. Many weeds and grasses that grow in pine nursery beds can be controlled with mineral spirits with no harm to pine seedlings. Although the same material is relatively harmless to sweetgum, hardwood seedlings in general are sensitive to herbicides. Therefore, the irksome and expensive task of weeding must be done by hand. To reduce the necessity for weeding, some nurserymen grow hardwood seedlings

at a dense spacing resulting in small, spindly plants. There is now universal agreement among hardwood managers that no hardwood seedling should be planted that measures less than 3/8 inch at the root collar; and the larger the diameter, the better will be the survival and growth. To achieve these sizes, it is necessary to use seed-bed densities of only six to ten per square foot. This means thinning and hand weeding for most species, with much higher seedling production costs than for pine.

Some nurserymen believe that row planting of hardwood seeds, as opposed to bed planting, will allow thinning and weeding to be mechanized and the cost lowered. In any event, it seems reasonable that greater specialization in hardwood seedling production will reduce costs below the current level.

The best estimates available as to the total cost of establishing hardwoods range from \$75/acre to \$125/acre, and these estimates agree with costs reported by Dutrow (1970) for cottonwood establishment. Minimum hardwood cultural requirements are very expensive compared with pine, yet good growth can insure an acceptable rate of return if harvest prices are sufficiently high. Cost per acre will be minimized when large acreages are planted, and when improved techniques are devised for the production of quality hardwood seedlings.

DETERMINATION OF VOLUME

Total volume (TV) was calculated for each species by the equation $TV = .00204(DBH)^2(HT) - .6477$ found in the U.S. Forest Service Research Note SO-113. Although this equation was developed for cottonwood, stem analysis of plantation grown trees of sycamore, sweetgum, and yellow poplar indicate that their volume is predicted with suitable accuracy. This can be explained by the similarity of form of most trees grown in plantations where age and spacing are constant. Sufficient samples were obtained to allow the calculation of yield equations for the above three species.

ECONOMIC ANALYSIS

Each species was evaluated according to the following financial criteria over a range of establishment costs, harvest values, and interest rates:

1. The optimum rotation length (financial maturity) of a plantation, in years, based upon a volume production function over time and a particular set of costs, returns, and interest rate assumptions. Optimum rotation is the age which maximizes the net present value of a series of plantations through time, and is the Faustmann criterion of maximizing soil rent or land expectation value (Hiley, 1956).
2. The maximum present value (soil rent or soil expectation value) of all future rotations, which will occur when each plantation is harvested at the optimum age.
3. The present value of one rotation, rather than of all future rotations, when harvested at the optimum rotation length.

All calculations assume that the combined cost for taxes and administration is \$1 per acre per year, and that all costs and revenues have been taken into account. Many companies earn revenues in addition to wood values from hunting leases and other alternatives, but these have been ignored in the present calculations. As long as hunting leases are on an acreage basis and are not variable by plantation age, there is no effect on optimum rotation length even though the bare land value is increased.

VOLUME PRODUCTION AND FINANCIAL EVALUATION BY SPECIES

A primary goal of this study was to determine yield equations (production functions) to relate volume growth to age. Plots have been grouped for calculation purposes by species, soil type, and establishment procedures. The groupings are shown below:

<u>Species</u>	<u>Number of Plantations Used in Calculations</u>	<u>Soil Group</u>	<u>Age Range</u>	<u>Establishment Procedures</u>
Sycamore	14	1	3-27	Cultivated ^a
Yellow-Poplar	11	2	7-33	Old field, no cultivation
Sweetgum	14	3	4-33	Old field, no cultivation ^b

^aOne 27-year-old plot was on an old field and the plantation had not been cultivated. It was included to extend the range of the data.

^bOne plot on Group 1 soil was cultivated; another plot on Group 2 soil was not cultivated.

SYCAMORE

The data obtained for sycamore are from stands grown on good sites and with cultivation. Most stands were established at 8' x 8' or 10' x 10' spacing, and most were not thinned. The resulting yield equation is:

$$V = \text{total volume per acre (cu.ft.)}$$

$$V = 321.7 (\text{age}) - 3.1 (\text{age})^2 - 980.6$$

$$(71.88) \quad (2.43)$$

The R^2 for the regression is 0.92, and the standard error is 483.4 cubic feet.

The cubic foot volume predicted by the sycamore yield equation was evaluated financially at prices ranging from \$0.06/cubic foot to \$0.20/cubic foot, at establishment costs of \$75 and \$100 per acre and at 6, 8, and 10 percent interest rates (Tables 1 & 2).

For example, when establishment costs are \$100 per acre, taxes and administration are \$1 per acre per year, net stumpage value is \$0.12/cubic foot, the interest rate is 6 percent, the optimum rotation length is 15 years, the maximum soil rent is \$82, and present value for one rotation is \$47. An alter-

SYCAMORE

Table 1. Optimum rotation length, maximum soil expectation value, and single rotation present value (establishment costs \$75/acre, tax and administration \$1/acre/year)^a

<u>\$/Cu.Ft.</u>	<u>Optimum Rotation (Years)</u>			<u>Maximum Soil Rent (\$)</u>			<u>Single Rotation Present Value(\$)</u>		
	<u>6%</u>	<u>8%</u>	<u>10%</u>	<u>6%</u>	<u>8%</u>	<u>10%</u>	<u>6%</u>	<u>8%</u>	<u>10%</u>
.06	17	16	15	(9)	(35)	(49)	(6)	(25)	(32)
.08	15	14	13	34	(6)	(28)	20	(4)	(20)
.10	14	13	12	80	24	(7)	44	15	(4)
.12	14	13	12	126	55	16	70	35	11
.14	13	12	11	172	87	39	91	52	25
.16	13	12	11	219	119	63	116	72	41
.18	13	12	11	267	151	86	142	91	56
.20	12	11	11	314	183	110	158	105	71

^aParentheses indicate negative values.

SYCAMORE

Table 2. Optimum rotation length, maximum soil expectation value, and single rotation present value (establishment costs \$100/acre, tax and administration \$1/acre/year)^a

<u>\$/Cu.Ft.</u>	<u>Optimum Rotation (Years)</u>			<u>Maximum Soil Rent (\$)</u>			<u>Single Rotation Present Value(\$)</u>		
	<u>6%</u>	<u>8%</u>	<u>10%</u>	<u>6%</u>	<u>8%</u>	<u>10%</u>	<u>6%</u>	<u>8%</u>	<u>10%</u>
.06	19	18	17	(48)	(70)	(82)	(32)	(52)	(65)
.08	17	16	15	(6)	(43)	(62)	(4)	(30)	(47)
.10	16	14	14	37	(14)	(42)	22	(9)	(31)
.12	15	14	13	82	16	(20)	47	11	(14)
.14	14	13	12	127	46	2	71	30	2
.16	14	13	12	173	78	25	97	49	17
.18	13	12	11	220	109	48	117	66	31
.20	13	12	11	267	141	71	142	85	46

^aParentheses indicate negative values.

native way of looking at the values in Table 2 is that if the land investment is \$82 per acre, and establishment costs are \$100 per acre, sycamore wood must be valued at \$.12 per cubic foot if the total investment is to earn 6 percent.

A company that is not selling stumpage on the open market could determine the net stumpage value per cubic foot from a given tract as a shadow price:

$$$/\text{cubic foot} = D - H - T$$

Where:

D = Delivered mill price per cubic foot of externally obtained wood,
H = Cost per cubic foot for harvest of plantation wood,
T = Cost per cubic foot for transportation from plantation to the mill.

Other things being equal, plantations close to the mill have the highest net value, the shortest optimum rotation length, and the highest present value. Therefore, land is more valuable near the mill. As interest rates increase, optimum rotation length decreases. Conversely, as establishment, harvest, or transportation costs go up, optimum rotation age goes up and present values go down. Higher constant annual costs do not affect optimum rotation length, but they do lower present values.

The appropriate set of values within these ranges can be chosen best by the individual who is contemplating growing sycamore. It is unlikely anyone can establish and cultivate a plantation for one year on former forest land for \$75 per acre; a more reasonable estimate of the investment through the first growing season is \$90 to \$120 per acre. There is the possibility with hardwood species, sycamore included, of growing additional coppice (sprout) crops from the original rootstocks. If the same yield equation holds for coppice rotations, at least for a couple of additional rotations, the attractiveness of the investment increases. For example, assuming an initial establishment cost of \$100 and subsequent coppice rotation costs of \$75 at the beginning of each new rotation, the appropriate rotation length is obtained from the \$75/acre table and soil rent (land value) in that table should be reduced by \$25/acre ($\$100 - \$75 = \25). Specifically, if a sycamore plantation is established for \$100 per acre, and is subsequently regenerated for \$75 per acre at an interest rate of 8 percent and a residual stumpage value of \$0.16/cubic foot, the optimum rotation length is 12 years, the present value of all future rotations (maximum soil expectation value) is $\$119 - \$25 = \$94$, the present value per acre of the first rotation is $\$72 - \$25 = \$47$, and each subsequent plantation has a discounted value of \$72 at the beginning of the rotation (Table 1).

While it is unreasonable to expect the yield equation to hold over many coppice rotations, allowing it to hold for two rotations subsequent to initial establishment results in the value for maximum bare land value for the three rotations being similar to that for an infinite series. Even if coppice regeneration is not used, reestablishment of second or third plantations is certain to be less costly than for the first plantation due to the relative absence of unmerchantable debris.

YELLOW-POPLAR

Yellow-poplar is not a generally preferred species for pulping but its value for lumber has generated some interest in plantation establishment. Most of the plantations located were in the North Carolina mountains, all were on old fields, and none had been cultivated or fertilized. The yield equation is:

$$V = \text{Total volume/acre (cu.ft.)}$$

$$V = 285.55 (\text{age}) - 4.06 (\text{age})^2 - 1073.65$$
$$(133.67) \quad (3.29)$$

$$(R^2 = .71; \text{standard error} = 775 \text{ cubic feet})$$

Because the data were obtained only from plots of Group 2 soils, care must be exercised in extrapolating to plantations on other soil groups. The values in tables 3 & 4 were calculated on the basis of the yellow-poplar yield equation in a parallel fashion to those calculated for sycamore.

There is the temptation to compare the present values of yellow-poplar and sycamore. However, this is not a valid comparison because the yellow-poplar yield equation is based on less productive soils. Attempts were made, to no avail, to locate plantations of both species on soils of the same group. Until this is done, valid species comparisons cannot be made.

Since most yellow-poplar plantations were located in one area (western North Carolina) there is some risk when extrapolating growth rates to other areas. For example, on loess soils and with cultivation, yellow-poplar plantings have grown to an average total height of 11 feet with 95 percent survival after two growing seasons.² If these growth rates are maintained at a moderately decreasing rate, the per acre yields suggested are somewhat greater than the above yield equation predicts, however risky such speculation may be. If yellow-poplar plantations are grown for both pulp and lumber production, rotation lengths would be lengthened by the effect of sawtimber values at older ages and by the intermediate harvest value of pulp thinnings.

SWEETGUM

There is no native hardwood that occupies a wider range of sites, but for various reasons the species has generally been scorned. Of the plantations located, most were grown on Group 3 soils, and of these none were cultivated. Some were on old fields, others were on cleared forest land. There was considerable variability in performance among plantations. After testing several models, the following simple linear one was found to fit the data best:

²Personal communication with Mr. W. L. Bond, Grief Bros., Vicksburg, Miss.

native way of looking at the values in Table 2 is that if the land investment is \$82 per acre, and establishment costs are \$100 per acre, sycamore wood must be valued at \$.12 per cubic foot if the total investment is to earn 6 percent.

A company that is not selling stumpage on the open market could determine the net stumpage value per cubic foot from a given tract as a shadow price:

$$\$/\text{cubic foot} = D - H - T$$

Where:

D = Delivered mill price per cubic foot of externally obtained wood,
H = Cost per cubic foot for harvest of plantation wood,
T = Cost per cubic foot for transportation from plantation to the mill.

Other things being equal, plantations close to the mill have the highest net value, the shortest optimum rotation length, and the highest present value. Therefore, land is more valuable near the mill. As interest rates increase, optimum rotation length decreases. Conversely, as establishment, harvest, or transportation costs go up, optimum rotation age goes up and present values go down. Higher constant annual costs do not affect optimum rotation length, but they do lower present values.

The appropriate set of values within these ranges can be chosen best by the individual who is contemplating growing sycamore. It is unlikely anyone can establish and cultivate a plantation for one year on former forest land for \$75 per acre; a more reasonable estimate of the investment through the first growing season is \$90 to \$120 per acre. There is the possibility with hardwood species, sycamore included, of growing additional coppice (sprout) crops from the original rootstocks. If the same yield equation holds for coppice rotations, at least for a couple of additional rotations, the attractiveness of the investment increases. For example, assuming an initial establishment cost of \$100 and subsequent coppice rotation costs of \$75 at the beginning of each new rotation, the appropriate rotation length is obtained from the \$75/acre table and soil rent (land value) in that table should be reduced by \$25/acre (\$100 - \$75 = \$25). Specifically, if a sycamore plantation is established for \$100 per acre, and is subsequently regenerated for \$75 per acre at an interest rate of 8 percent and a residual stumpage value of \$0.16/cubic foot, the optimum rotation length is 12 years, the present value of all future rotations (maximum soil expectation value) is \$119 - \$25 = \$94, the present value per acre of the first rotation is \$72 - \$25 = \$47, and each subsequent plantation has a discounted value of \$72 at the beginning of the rotation (Table 1).

While it is unreasonable to expect the yield equation to hold over many coppice rotations, allowing it to hold for two rotations subsequent to initial establishment results in the value for maximum bare land value for the three rotations being similar to that for an infinite series. Even if coppice regeneration is not used, reestablishment of second or third plantations is certain to be less costly than for the first plantation due to the relative absence of unmerchantable debris.

YELLOW-POPLAR

Yellow-poplar is not a generally preferred species for pulping but its value for lumber has generated some interest in plantation establishment. Most of the plantations located were in the North Carolina mountains, all were on old fields, and none had been cultivated or fertilized. The yield equation is:

$$V = \text{Total volume/acre (cu.ft.)}$$

$$V = 285.55 (\text{age}) - 4.06 (\text{age})^2 - 1073.65$$
$$(133.67) \quad (3.29)$$

$$(R^2 = .71; \text{standard error} = 775 \text{ cubic feet})$$

Because the data were obtained only from plots of Group 2 soils, care must be exercised in extrapolating to plantations on other soil groups. The values in tables 3 & 4 were calculated on the basis of the yellow-poplar yield equation in a parallel fashion to those calculated for sycamore.

There is the temptation to compare the present values of yellow-poplar and sycamore. However, this is not a valid comparison because the yellow-poplar yield equation is based on less productive soils. Attempts were made, to no avail, to locate plantations of both species on soils of the same group. Until this is done, valid species comparisons cannot be made.

Since most yellow-poplar plantations were located in one area (western North Carolina) there is some risk when extrapolating growth rates to other areas. For example, on loess soils and with cultivation, yellow-poplar plantings have grown to an average total height of 11 feet with 95 percent survival after two growing seasons.² If these growth rates are maintained at a moderately decreasing rate, the per acre yields suggested are somewhat greater than the above yield equation predicts, however risky such speculation may be. If yellow-poplar plantations are grown for both pulp and lumber production, rotation lengths would be lengthened by the effect of sawtimber values at older ages and by the intermediate harvest value of pulp thinnings.

SWEETGUM

There is no native hardwood that occupies a wider range of sites, but for various reasons the species has generally been scorned. Of the plantations located, most were grown on Group 3 soils, and of these none were cultivated. Some were on old fields, others were on cleared forest land. There was considerable variability in performance among plantations. After testing several models, the following simple linear one was found to fit the data best:

²Personal communication with Mr. W. L. Bond, Grief Bros., Vicksburg, Miss.

YELLOW-POPLAR

Table 3. Optimum rotation length, maximum soil expectation value, and single rotation present value (establishment costs \$75/acre, tax and administration \$1/acre/year)^a

<u>\$/Cu. Ft.</u>	<u>Optimum Rotation (Years)</u>			<u>Maximum Soil Rent (\$)</u>			<u>Single Rotation Present Value(\$)</u>		
	<u>6%</u>	<u>8%</u>	<u>10%</u>	<u>6%</u>	<u>8%</u>	<u>10%</u>	<u>6%</u>	<u>8%</u>	<u>10%</u>
.06	18	17	16	(43)	(57)	(65)	(28)	(42)	(51)
.08	17	16	15	(13)	(37)	(51)	(8)	(26)	(39)
.10	16	15	14	19	(16)	(36)	12	(11)	(26)
.12	15	14	13	52	6	(20)	30	4	(14)
.14	14	13	13	85	28	(4)	48	18	(3)
.16	14	13	12	119	51	12	66	32	8
.18	14	13	12	153	73	29	85	46	20
.20	13	12	12	187	96	45	99	58	31

^aParentheses indicate negative values.

YELLOW-POPLAR

Table 4. Optimum rotation length, maximum soil expectation value, and single rotation present value (establishment costs \$100/acre, tax and administration \$1/acre/year)^a

<u>\$/Cu.Ft.</u>	<u>Optimum Rotation (Years)</u>			<u>Maximum Soil Rent (\$)</u>			<u>Single Rotation Present Value(\$)</u>		
	<u>6%</u>	<u>8%</u>	<u>10%</u>	<u>6%</u>	<u>8%</u>	<u>10%</u>	<u>6%</u>	<u>8%</u>	<u>10%</u>
.06	21	20	19	(80)	(90)	(96)	(56)	(71)	(80)
.08	18	17	16	(52)	(72)	(83)	(34)	(53)	(65)
.10	17	16	15	(22)	(52)	(69)	(14)	(37)	(53)
.12	16	15	14	10	(32)	(54)	6	(22)	(40)
.14	15	14	14	42	(10)	(39)	24	(7)	(29)
.16	15	14	13	75	12	(23)	44	8	(17)
.18	14	13	13	108	34	(7)	60	21	(5)
.20	14	13	12	142	56	9	79	36	6

^aParentheses indicate negative values.

$V = \text{Total volume/acre (cubic feet)}$

$V = 104.69(\text{age}) - 556.85$
(21.21)

$R^2 = .69$, standard error = 648 cubic feet)

It is certain that sweetgum will perform better on soils superior to those on which the present plantations are found. One plantation found on Group 1 soil produced 749 cubic feet at age 7 (vs. 176 cubic feet from the equation), and another on Group 2 soil produced 1976 cubic feet at age 13 (vs. 804 feet from the equation). With such limited data from the better sites, the calculated production function only estimates sweetgum performance on marginal hardwood sites where the species was established with pine planting techniques and probably with inferior seedlings. Any direct comparison between sycamore, established on the best sites and receiving cultivation, and sweetgum established by pine planting techniques on the poorer soils, will be misleading.

Tables of calculations for sweetgum are not presented since present values are all negative at establishment costs of \$75 and \$100 per acre. The establishment cost of most of the plantations measured was probably under \$50 per acre, since all but one were established using pine techniques. However, these costs are misleading because a majority of the plantations failed completely, resulting in a very high cost per acre of live plantation. The conclusion is that sweetgum plantations on marginal sites are poor investments. The use of more intensive management techniques on better soils will certainly result in a higher growth rate and perhaps yield a higher net return, but data are not yet available to confirm this speculation.

DISCUSSION

The available data indicate that the management of hardwoods in plantations may be economically feasible. Companies who need the product qualities added by hardwoods can economically justify hardwood plantations only on the better sites and at certain price levels. If the average land investment is taken to be \$80 per acre, then at a 6% interest rate, and \$100 establishment costs, sycamore plantations on the best soils become profitable at about \$.12/cubic foot, and yellow poplar on average soils becomes profitable at about \$16/cubic foot.

Matching the species to the soil is the most restrictive limitation to hardwood plantation management. It should be reiterated that hardwood prices must soar to extremely high levels to make production on marginal sites feasible. Increasing world prices for soybeans and feed grains will make the opportunity cost of growing trees on the best soils increasingly more expensive, but there are many bottomland sites with excellent soil that are too wet for agriculture but which can produce excellent tree crops. It is generally possible to operate equipment on these areas during the dry seasons to establish a plantation. Where such lands are available they will likely be the most economical choice for hardwood production.

The failure rate of past hardwood plantings should not be considered as evidence that hardwoods cannot be successfully grown. With the use of proper techniques, the uncertainty regarding survival and growth rates can be reduced to a level that will justify hardwood plantations at some current stumpage prices.

In summary, many questions remain concerning the financial returns from various degrees of site preparation and cultivation for different hardwood species. But we now know this much--consistently good survival and growth require the following:

1. Plantations on Group 1 and 2 soils
2. Large, healthy seedlings
3. Intensive site preparation, including subsoiling and cultivation in most circumstances, or bedding on sites that are frequently flooded
4. Fertilization, except on Group 1 soils, if plantations are to be cultivated
5. Proper seed source

When prices, either current or anticipated, rise to a level that stimulates serious interest in producing hardwoods in plantations, it appears that expensive establishment costs can be financially justified; in fact, the evidence indicates that efforts to establish hardwood plantations with inferior seedlings, poor competition control, or on marginal sites, cannot be justified at any price.

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GEOGRAPHIC VARIATION OF SWEETGUM

Jerry Sprague and Robert J. Weir^{1/}

Abstract.--A range-wide sweetgum (Liquidambar styraciflua) provenance study was established in 1966 to assess the variation in survival, growth and quality traits associated with differences among trees in stands, among stands, and among geographic sources.

Seed were collected from five trees from each of two stands from each of 14 sources across the south and southeastern United States. Outplantings were established in each of the 14 seed source areas.

Fourth year results indicate that tree to tree differences are sufficiently great to warrant a mass selection program for genetic improvement of the species. However, the greatest source of difference was among stands, indicating that greatest genetic gains could be obtained by selecting the best stands and then selecting the best trees from those stands. Although the trend is not strong, there is evidence that Coastal Plain sources are superior to Piedmont sources when planted in the Coastal Plain. When planted in the Piedmont, Coastal Plain sources perform equally well as the local sources but are more susceptible to environmental extremes.

During the past 15 years great advancement has been made in the application of tree improvement principles to southern pine silviculture. However, progress with southern hardwood tree improvement has lagged. Only now are we realizing results from basic variation studies of commercially important hardwood species.

To develop a sound breeding program for any species one must have a fundamental knowledge of the variation of economically important characteristics and how these characteristics are genetically controlled. Seed source testing is a meaningful beginning to understanding the pattern of variation. Seed source tests can also help delineate seed collection zones. For a species as widely distributed as sweetgum (Liquidambar styraciflua L.), there exists, in all probability, inherent differences between populations; these differences can dictate the choice of seed adapted to a particular area. Normally, the local seed source is best because it contains trees adapted to the local environmental conditions. However, in large scale forestry, a sufficient supply of suitable local seed may not always be available, resulting in the necessity of obtaining seed from a distant source.

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A Southwide sweetgum seed source study was established in 1967, under the direction of the N. C. State University - Industry Hardwood Research Program. The objectives of the study were:

1. To determine within stand, between stand, the geographic variation in growth rate, tree form, wood specific gravity, and fiber length from 14 sweetgum sources in the Southeast;
2. To differentiate performance and growth of these sources when established in the environmental conditions of other sources;
3. To indicate desirable sources of sweetgum for planting and, when local seed is unavailable, guide the selection of alternative sources;
4. To establish heritabilities of growth, form, and wood properties through parent-progeny correlations and to determine the changes in heritability estimates when the same material is grown under a variety of environments.

Assessment of height growth after the 4th growing season in the field has resulted in information pertaining to objectives 2, 3, and part of 1 which is discussed in this presentation.

METHODS AND MATERIALS

Seed were collected from natural sweetgum stands from seven transects across the Southeast. The first five transects were divided into Coastal and Piedmont zones, the first four being orientated east-west and the fifth north-south. The sixth and seventh transects are oriented east-west (northeast-southwest), comparing sources of the Mississippi Delta to the Louisiana upland and the Sabine River drainage to the Neches River drainage of eastern Texas (Fig. 1).

Within each collection zone seed were obtained from five mother trees in each of two stands (2 stands/collection zone x 2 zones/transect x 7 transects x 5 trees per stand = 140 parent trees.) Assuming that sweetgum management of the future would be on the better sites, seed sources were obtained from average or better sites. A listing of seed sources is shown in Table 1.

Seed collections were made in 1964 and 1965, sown in the nursery in 1966 and outplanted in the field in Spring, 1967. An outplanting was established in each of the 14 collection zones. Good sites were selected for the outplantings as sweetgum management will most likely be restricted to the better sites (Table 1).

Each outplanting included seedlings from the immediate transect plus seedlings from the two adjacent transects. The most northerly plantation included seedlings from the most western transect and vice versa so that all plantations included seedlings from three transects.

Seedlings were planted in 12-tree row plots by mother tree. The five mother-tree seed lots from each stand were planted together as a unit with randomization of seed lots in each unit. The mother tree units were randomized within each of 6 replications. To date, four of the outplantings have been abandoned (4-A, 4-B, 6-B, and 7-B) due mainly to poor survival, leaving 10 from which the 1970-71 measurements were obtained.

Fig. 1. Parent tree and seed collection locations (★):

Sweetgum Seed Source Study

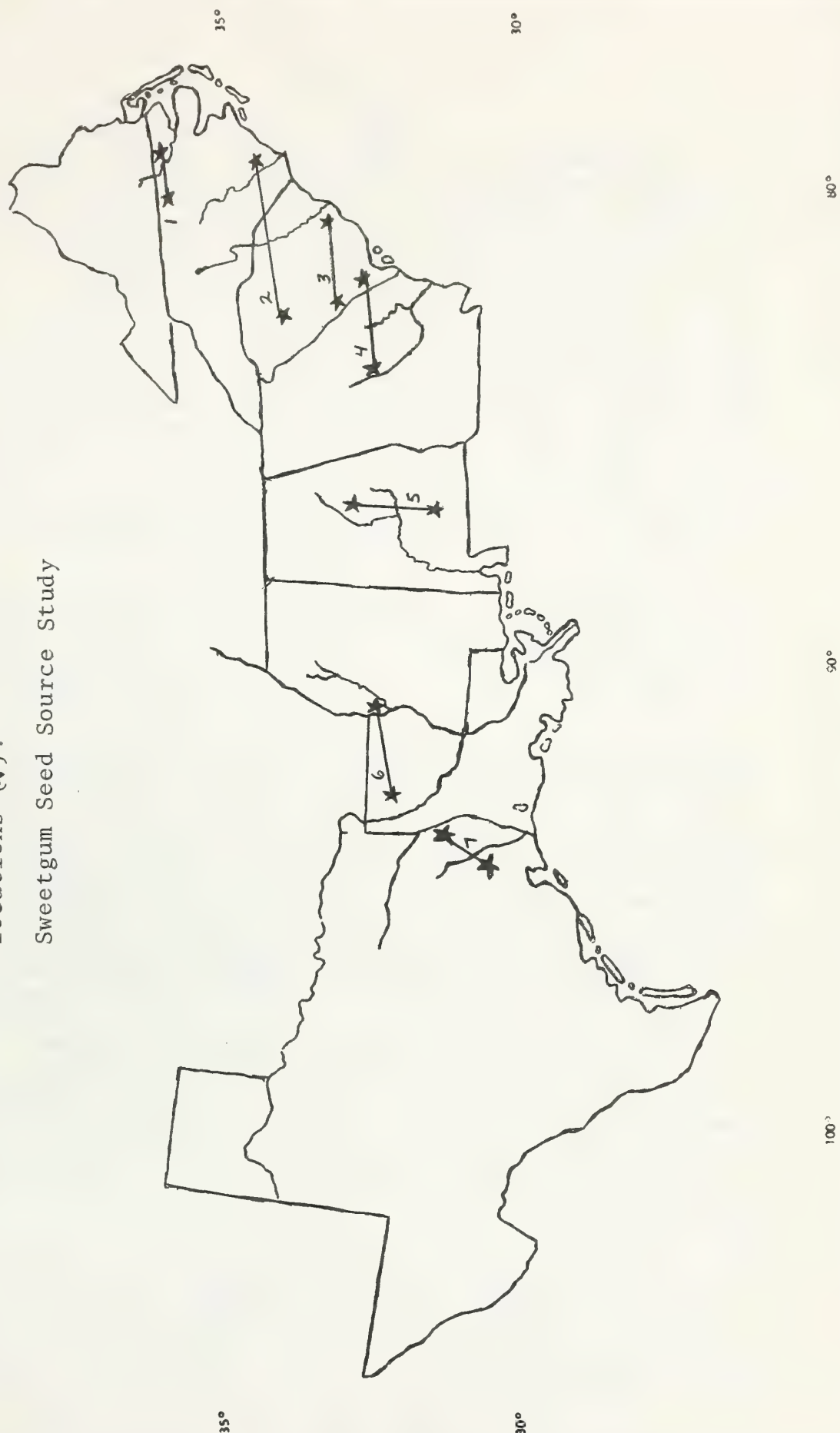


Table 1. Seed Collection and outplanting locations

Source Code ^{1/}	Exact Source	Approx. lati- tude	Out- planting	Approximate Location of Outplanting
1A1	Halifax County, N. C.	36°20'	1A	Bertie County, N. C.
1A2	Bertie County, N. C.	"	"	"
1B1	Granville County, N. C.	36°20'	1B	Greensville County, Va.
1B2	Granville County, N. C.	"	"	"
2A1	Bladen County, N. C.	34°40'	2A	Elizabethtown, N. C.
2A2	Bladen County, N. C.	"	"	"
2B1	Newberry County, S. C.	34°30'	2B	Clinton, S. C.
2B2	Newberry County, S. C.	"	"	"
3A1	Georgetown County	33°15'	3A	Georgetown County, S. C.
3A2	Georgetown County, S. C.	"	"	"
3B1	Saluda County, S. C.	33°15'	3B	Edgefield County, S. C.
3B2	Saluda County, S. C.	"	"	"
4A1	Allendale County, S. C.	33°00'	4A	Allendale County, S. C.
4A2	Allendale County, S. C.	"	"	"
4B1	Bibb County, Ga.	33°00'	4B	Twiggs County, Ga.
4B2	Monroe County, Ga.	"	"	"
5A1	Barbour County, Ala.	31°30'	5A	Butler County, Ala.
5A2	Monroe County, Ala.	"	"	"
5B1	Coosa County, Ala.	33°15'	5B	Tallapoosa County
5B2	Clay County, Ala.	"	"	"
6A1	Warren County, Miss.	32°30'	6A	Jefferson County, Miss.
6A2	Warren County, Miss.	"	"	"
6B1	Bienville Parish, La.	32°30'	6B	Bienville Parish, La.
6B2	Winn Parish, La.	"	"	"
7A1	Sabine County, Texas	31°15'	7A	Zwolle, La.
7A2	Sabine County, Texas	"	"	"
7B1	Angelina County, Texas	31°15'	7B	Neches River, Texas
7B2	Angelina County, Texas	"	"	"

The code for the sweetgum seed source test is:

Four digit number.

First digit - A number corresponding to the transect number. One being the northeasternmost and seven the southwesternmost.

Second digit- A letter, either A or B. A connotes a coastal source and B a Piedmont source.

Third digit - A number differentiating one of two stands representing the collection location.

Fourth digit - Tree number - Five trees were chosen as half-sib family parents in each stand.

^{1/} The source only includes the first three numbers of the code.

RESULTS

Total height growth after four growing seasons in the field was assessed separately for each of the 10 plantations. Analyses of variance (Table 6) and means were computed to discern important differences attributable to geographic source (transects and physiographic regions), stands and trees (families) within stands. Combined analyses were not attempted because of the substantial imbalance encountered between plantings, however, general trends are apparent from the overview of the 10 distinct analyses.

Transects - In general, differences in height growth associated with transects were unimportant and not detectable within the regions defined by the 3-transect comparison (Tables 4 and 6). The results were inconclusive when the most southern source was included in the most northern plantation and when the most northern source was included in the most southern plantation. In plantation 1A, the Coastal Plain plantation of the most northern transect (Bertie Co., N. C.), families from stand 7A2 (Sabine Parish, La.) averaged about a foot taller than the plantation average. At the companion Piedmont plantation (1B), where the difference in height growth between tallest and shortest sources was less than one foot, the 7A2 source was only average (Table 3).

A detailed examination of plantation 2B (Newberry, S. C.) was conducted to determine the effect of frost on several sources represented in that plantation. The sources from Alabama, Mississippi, Louisiana, and Texas suffered considerably more damage than the local ones from North Carolina and South Carolina (Table 2).

From these results it appears that we can collect seed for a given area from within a 3-transect region without fear of growth loss but that we should not move the extreme southern sources as far north as South Carolina.

Physiographic region - Examination of the means for Coastal Plain and Piedmont sources reveals some evidence that the Coastal sources are superior to the Piedmont sources when planted in the Coastal Plain (Table 5). When planted in the Piedmont, Coastal Plain sources performed equally as well as the local sources; however, it is suspected that the Coastal Plain sources are more susceptible to environmental extremes as indicated by the frost damage encountered at Newberry, S. C. No statistical differences between regions were found (Table 6).

Stand - The greatest source of variation in height growth was attributed to the stand component (Table 6). This result is similar to that found for wood specific gravity of the parent trees of this study (Johnson and McElwee, 1967). Studies on sycamore have also shown the stand component of variation to be greater than the tree-to-tree differences within stands (Schmitt and Webb, 1971; Lee, 1973; Schmitt and Wilcox, 1969). Such large differences among stands imply that the greatest genetic gain can be obtained by first locating the best stands and then locating the best trees within these stands. Since it would be very difficult to select the best stands with respect to growth without actually testing, a possible approach would be to relax selection so that the best trees in many natural stands could be evaluated, followed by intensive selection in the resulting foundation populations, as suggested by Schmitt and Wilcox (1969). This approach is similar to the mother tree studies being

Table 2. Cold Damage to Several Sweetgum Sources
Planted in Newberry, S. C.

<u>Averages by Source</u>		
<u>Source</u>	<u>Extent of damage*</u>	<u>% Infected</u>
Halifax and Bertie Cos., N. C.	.18	2.0
Granville Co., N. C.	.24	2.4
Bladen Co., N. C.	.50	4.8
Newberry Co., S. C.	.22	2.2
Georgetown, S. C.	.69	6.7
Saluda Co., S. C.	.55	4.0
Barbour and Monroe Cos., Ala.	1.0	14.0
Coosa and Clay Cos., Ala.	.6	6.0
Warren Co., Miss.	1.0	14.0
Bienville and Winn Parishes, La.	2.0	30.0
Sabine Co., Texas	2.0	2.0
Angelina Co., Texas	2.0	27.5

* Extent of damage was recorded according to the following code:

None = 0

Light = top 1/4 or less of tree killed = 1

Moderate = top 1/4 - 1/2 of tree killed = 2

Heavy = Killed to ground or nearly so = 3

Table 3. HEIGHT MEANS (IN FEET AND TENTHS) BY STAND FOR EACH PLANTATION

Plantation	1A Coastal, N.C.		1B Piedmont, N.C.		2A Coastal, N.C.		2B Piedmont, S.C.		3A Coastal, S.C.	
	Stand	Ht.	Stand	Ht.	Stand	Ht.	Stand	Ht.	Stand	Ht.
	7A2	7.6	2B2	3.2	1A1	3.0	2B2	10.0	4B1	5.2
	2A1	7.1	2A1	3.0	2A1	3.0	2A2	9.6	2A1	5.1
	2A2	6.9	1A1	2.8	1B2	2.7	3B1	9.2	4A2	4.8
	1B2	6.8	1B1	2.8	3B1	2.7	1B2	9.2	3B1	4.6
	2B2	6.7	2A2	2.8	3A2	2.6	3A2	9.1	3A2	4.5
	7B2	6.6	1A2	2.7	1A2	2.6	1A1	8.8	4A1	4.5
	1A2	6.6	1B2	2.7	2A2	2.6	2A1	8.7	3A1	4.3
	7A1	6.5	2B1	2.6	2B2	2.4	3A1	8.6	2A2	4.2
	1A1	6.4	7A2	2.6	3A1	2.4	1A2	8.4	2B1	4.0
	1B1	6.4	7A1	2.4	1B1	2.3	1B1	8.2	3B2	3.9
	2B1	6.3	7B1	2.4	2B1	2.2	2B1	8.2		
	7B1	5.9								

Plantation	3B Piedmont, S.C.		5A Coastal, Ala.		5B Piedmont, Ala.		6A Upper Coastal Miss.		7A Upper Coastal Texas	
	Stand	Ht.	Stand	Ht.	Stand	Ht.	Stand	Ht.	Stand	Ht.
	2A1	5.8	6B2	6.7	6B1	5.7	6B2	6.3	7A2	6.3
	4B1	5.2	5A2	6.2	4A1	5.7	6A1	6.0	6B2	6.1
	2B2	5.0	6A2	5.7	4A2	5.6	7A2	5.9	6B1	6.1
	3B1	5.0	5B1	5.7	5A2	5.6	7B2	5.8	7A1	6.0
	3B2	5.0	4B1	5.6	4B2	5.5	5A2	5.7	7B1	6.0
	4A1	4.9	6A1	5.5	6B2	5.1	6A2	5.6	1B2	5.9
	3A2	4.7	4A2	5.4	4B1	4.6	6B1	5.6	7B2	5.9
	2B1	4.6	5A1	5.4	6A1	4.5	7A1	5.6	1A2	5.8
	4A2	4.5	5B2	5.4	6A2	4.4	5A1	5.5	1A1	5.6
	2A2	4.4	6B1	5.4	5B1	4.4	5B1	5.4	6A1	5.6
	3A1	4.1	4B2	5.2	5A1	4.2	7B1	5.4	1B1	5.4
			4A1	4.5	5B2	4.2	5B2	5.0	6A2	5.3

Table 4. Ht. means by transect at each plantation (in ft. and tenths)

	<u>Plantations</u>				
	1A Coastal <u>N. C.</u>	1B Piedmont <u>N. C.</u>	2A Coastal <u>N. C.</u>	2B Piedmont <u>S. C.</u>	3A Coastal <u>S. C.</u>
Transect	1 - 6.6	1 - 2.8	1 - 2.6	1 - 8.6	2 - 4.5
Transect	2 - 6.7	2 - 2.9	2 - 2.6	2 - 9.1	3 - 4.3
Transect	7 - 6.8	7 - 2.5	3 - 2.6	3 - 9.0	4 - 4.7
	3B Piedmont <u>S. C.</u>	5A Coastal <u>Ala.</u>	5B Piedmont <u>Ala.</u>	6A Upper Coastal <u>Miss.</u>	7A Upper Coastal <u>Texas</u>
Transect	2 - 5.0	4 - 5.2	4 - 5.3	5 - 5.4	1 - 5.7
Transect	3 - 4.7	5 - 5.7	5 - 4.6	6 - 5.9	6 - 5.8
Transect	4 - 4.9	6 - 5.8	6 - 5.0	7 - 5.7	7 - 6.0

Table 5. Ht. means (in feet and tenths) by physiographic region at each plantation

	1A Coastal <u>N. C.</u>	1B Piedmont <u>N. C.</u>	2A Coastal <u>N.C.</u>	2B Piedmont <u>S.C.</u>	3A Coastal <u>S.C.</u>
Coastal Plain	6.8	2.8	2.8	8.9	4.6
Piedmont	6.5	2.8	2.4	8.9	4.2
	3B Piedmont <u>S. C.</u>	5A Coastal <u>Ala.</u>	5B Piedmont <u>Ala.</u>	6A Upper Coastal <u>Miss.</u>	7A Upper Coastal <u>Texas</u>
Coastal Plain	4.8	5.5	5.0	5.7	5.8
Piedmont	4.9	5.6	4.9	5.6	5.9

Table 6. Analyses of variance of four year total height growth computed separately by planting.

Plantation	1A N. C. Coastal		1B N. C. Piedmont		2A N. C. Coastal		2B S. C. Piedmont		3A S. C. Coastal	
	D.F.	M.S.	D.F.	M.S.	D.F.	M.S.	D.F.	M.S.	D.F.	M.S.
Replications	5		5		5		4		5	
Geographic source	5	4.45	5	1.63	5	2.38	5	2.75	5	2.36
lat. transects	2	0.60	2	3.75	2	0.48	2	4.96	2	0.24
physiographic region	1	10.06	1	0.03	1	5.72	1	0.25	1	6.44
trans x region	2	5.48	2	0.62	2	2.60	2	1.79	2	2.50
Stands/source	6	2.55	5	0.74	5	1.41**	5	8.86**	4	4.38**
Family/stands	41	1.56**	38	0.37	37	0.16	37	2.42	32	1.00**
Error	260	.88	240	0.35	235	0.28	188	2.13	200	0.49

Plantation	3B S. C. Piedmont		5A Ala. Coastal		5B Ala. Piedmont		6A Miss. Upper Coastal		7A Texas Upper Coastal	
	D.F.	M.S.	D.F.	M.S.	D.F.	M.S.	D.F.	M.S.	D.F.	M.S.
Replications	5		5		5		5		5	
Geographic source	5	3.23	5	7.93	5	9.27	5	3.87	5	2.14
lat. transects	2	2.30	2	12.24	2	10.04	2	5.82	2	2.45
physiographic region	1	1.88	1	4.84	1	0.59	1	2.53	1	0.04
trans x region	2	4.84	2	5.18	2	12.84	2	2.59	2	2.88
Stands/source	5	7.97**	6	6.38**	6	5.83**	6	2.20*	6	1.21
Family/stands	36	0.92	45	1.00	44	0.52	46	0.71	48	0.77*
Error	230	0.96	280	1.73	275	1.29	285	0.66	295	0.54

* - denotes statistical significance at the .95 level of probability

** - denotes statistical significance at the .99 level of probability

conducted by the N. C. State University - Industry Hardwood Research Program. The best trees are selected from a very large number of stands and collectively these are tested with open-pollinated progeny. From the progeny, intensive selection for the very best trees in the best families is planned.

Families - Several studies conducted on southern hardwoods have shown that the variation among trees of a species is great enough to warrant mass selection programs (Roberds, 1965; Wilcox and Farmer, 1967; Kellison, 1971; Weir, 1971; Kitzmiller, 1972 and Sumantakul, 1973). Although the stand component was the largest source of variation in this sweetgum study there were significant family differences in a few of the plantations and it is felt that family differences are great enough to justify a mass selection program for genetic improvement of the species in the manner described above (Table 6).

SUMMARY AND CONCLUSIONS

1. Differences in height growth associated with transects were not detectable within any given region defined by its 3-transect companions. Therefore, we feel it safe to move sweetgum within a 3-transect region as defined by this study.
2. Results from plantations where the southern-most sources were planted in the northern-most areas of the study and vice versa were inconclusive. However, based on the frost damage encountered in the plantation at Newberry, S. C., we recommend that the Alabama, Mississippi, Louisiana, and Texas sources not be moved as far north as South Carolina.
3. Examination of data reveals that the Coastal sources should be restricted to the Coastal Plains and the Piedmont sources to the Piedmont areas in order to assure maximum survival and growth.
4. The large stand to stand differences indicate that the largest genetic improvement would be obtained by selecting the best trees out of the best stands for use in seed production.
5. Family differences were great enough to warrant a mass selection program as described in this paper.

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EARLY RESULTS FROM A CHERRYBARK OAK IMPROVEMENT PROJECT

W. K. Randall¹

Abstract.--At two cherrybark oak plantings in Tennessee and two in Arkansas, age-3 height of open-pollinated progeny varied significantly among families. Source differences were not significant in Arkansas. In Tennessee, progeny of the local trees were twice as tall as progeny of Arkansas and Mississippi trees. Progeny of phenotypically selected parents were significantly taller than the progeny from random parents at only one of four plantings. Survival of seedlings planted with bare roots or in milk cartons was significantly better than that of seedlings planted in paper tubes.

Additional keywords: Quercus falcata var. pagodaefolia, provenance, phenotypic selection.

Among southern oaks, cherrybark (Quercus falcata var. pagodaefolia Ell.) is a promising candidate for genetic improvement because it is the fastest growing and because it is found throughout the southern Coastal Plain and the lower Mississippi Valley. It grows best on well-drained, loamy soil where intensive forestry is expected. The study described here was undertaken jointly by the Southern Hardwoods Laboratory, the Tennessee Department of Conservation, and International Paper Company to determine whether there was sufficient genetic variation in the species to justify improvement efforts. Early results are promising.

METHODS

A total of 56 cherrybark oaks with above-average growth rates and straight boles free of surface abnormalities and epicormic branches were selected in natural stands in Tennessee, Mississippi, and Arkansas during fall in 1966 and 1967 (fig. 1). Form class and crown characteristics were also considered, but they were of secondary importance. Since trees were not assigned scores, the degree of superiority of the selections cannot be estimated. Emphasis was placed upon securing a large number of good trees rather than a few trees of extremely high quality. To judge the results of phenotypic selection, 39 additional trees were selected at random.

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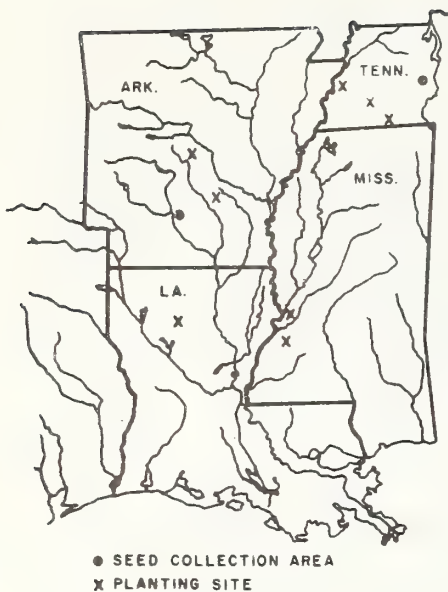


Figure 1.--Cherrybark oak seed collection areas and planting sites.

The acorn crop was scant in 1967, but sufficient numbers of acorns were obtained from 16 desirable and 16 randomly selected trees for progeny tests. In 1968 acorns were abundant, and they were collected from 56 desirable and 39 randomly selected trees.

Seedlings for plantings in Tennessee were grown at the Pinson nursery near Jackson, Tennessee. Those for Arkansas planting were grown at the Baucum nursery near Little Rock.

At the Pinson nursery, acorns were planted in nursery beds in early spring. At the Baucum nursery, they were planted in January in both nursery beds and containers. Here, 160 seeds from each family were sown in nursery beds, two seeds in each of 15 heavy cardboard mailing tubes (1.75 X 12 inches), and two seeds in each of 15 1-quart milk cartons (2.75 X 2.75 X 9 inches).

Seedlings were planted in randomized complete blocks at four locations, two near Lexington, Tennessee, with bare-rooted seedlings, and two near Fordyce, Arkansas, one with bare-rooted and the other with container stock (fig. 1). Plots representing single open-pollinated families contained either three or four trees at 9 X 9-foot spacing. Plots with bare-rooted seedlings were replicated six to 10 times, and those with each type of container were replicated twice. A planting at Scarce Creek, Tennessee, was made in January 1969 with seedlings from 1967 acorns. The other locations were planted with seedlings from 1968 acorns.

Tennessee sites were old fields and soil was Collins silt loam. The Arkansas plantings were on well-drained floodplain soil in the Ochlockonee series which was cleared 2 years prior to planting and freshly disked just prior to planting.

Bare-rooted seedlings (1-0) were planted during the dormant season, and container seedlings (3 months old) in June. Competing vegetation was greatest in Arkansas and consisted mostly of blackberry and dewberry. Ground cover in Tennessee was primarily Johnson and Timothy grasses. All areas were disked once and mowed once the first year after planting.

In October 1969, 1-year height and survival were recorded at Scarce Creek, Tennessee. Equivalent height and survival were taken on the Arkansas plantings during the fall of 1970. Height and survival were again recorded at all plantings during June 1972. Analyses of variance were made and statistical significance was determined at the 0.05 level.

RESULTS AND DISCUSSION

Arkansas plantings.--At age 1 survival was 82 percent for bare-rooted seedlings, 85 percent for those in cartons, and 77 percent for those in tubes. Differences among the three types of planting stock were not significant. Heights were not affected by type of planting stock or source area. Although families differed significantly, select families showed no superiority over random families in either height or survival.

After 3 years, survival of bare-rooted seedlings and those in cartons was 66 percent, whereas that of seedlings in tubes was 50 percent. This difference was statistically significant. Height was not affected by type of planting stock or source area, and survival of bare-rooted seedlings was not influenced by source. At age 3, mean family heights differed significantly, ranging from 0.9 to 2.1 feet. Desirable and randomly selected families performed equally well.

Tennessee plantings.--Survival was excellent in both Tennessee plantings: 93 percent at age 3 at Scarce Creek and 92 percent at age 2 at Foster Trail.

At age 1, the average height of select families at Scarce Creek was 1.1 feet, while that of random families was 0.9 feet--significantly shorter. At age 3, heights of select and random families were still significantly different (2.6 vs. 2.2 feet), as were heights among the 17 families.

At Foster Trail at age 2, the tree heights averaged 2.0 feet. Trees from Tennessee sources were taller than those from Mississippi and Arkansas sources (2.3 vs. 1.2 feet). There were no differences between the select and random groups from either the Tennessee or the Mississippi and Arkansas sources. However, within the Tennessee select and random groups, family differences were significant.

The effect of provenance was observed in two plantings. In the one in Arkansas no effect was discernible. At Foster Trail, Tennessee, local progeny were twice as tall as those from Mississippi and Arkansas (2.3 vs. 1.6 feet). Eighty percent of the height variation among families in this planting was due to source differences.

The primary purpose of the study was to learn whether genetic variation among cherrybark oaks is sufficient to consider a tree improvement program. Results through age 3 are encouraging. Variations in height growth among families were large at all planting sites.

The results of selection were inconsistent. At only one planting site were progenies of desirable trees significantly taller than those of randomly selected trees. Since selection was not primarily for height growth, the lack of consistent gains in height growth is not very disappointing. The lack of consistency may indicate a complex relationship between site and early height growth.

Currently available data are insufficient to plan selection strategy for cherrybark oak. Santamour and Schreiner (1961) and Schreiner and Santamour (1961) in tests of five species of white and five of red oak found frequent wide variations between progenies of two parents from the same locality. Kriebel (1965) found a strong effect of geographic origin on seedling growth rate, particularly when sampling a wide geographic distribution. Results of the present study indicate that both phenotypic and geographic selection may prove effective for cherrybark oak.

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IS VARIATION IN BUDBREAK OF RED OAK THE
RESULT OF HEREDITY OR ENVIRONMENT?

Charles E. McGee^{1/}

Abstract.--When outplanted over a wide range of elevations in the Southern Appalachians, northern red oak seedlings from sources at low elevations broke dormancy 11 days sooner than those from higher elevations. Variation within the three-tree sources averaged 3 days at a given outplanting site. This pattern in budbreak appears to persist for 8 or more years. Such variation greatly affects the ability of outplanted seedlings to withstand unseasonable cold weather and to compete with surrounding vegetation. At this time, it is difficult to tell whether the variation results from genetic differences or from environmental preconditioning of the sources.

Additional keywords: Quercus rubra, phenology, provenance.

In past years, many sound studies have been carried out that document the effect of provenance on seedling performance. As a result of these studies, few tree planters are willing to use seedlings from distant sources, until those sources are thoroughly tested. Usually, however, little thought is given to a source of seed if it is from reasonably close to the planting site. Such complacency may, in certain cases, be unwarranted.

I propose to discuss some of the implications of a study of the effect of seed-source elevation on the phenology of northern red oak (Quercus rubra L.). Early results of the study show that the time of budbreak varies considerably between seedlings from sources at different elevations. The overall importance of this finding to tree planters is not yet clear. But it is obvious that if seedlings from low-elevation sources are planted at higher elevations and break dormancy as if they are at a low elevation, the new vegetation will be exposed to the adverse weather normally associated with high elevations. Conversely, planted seedlings from a high-elevation source would have difficulty competing with the surrounding vegetation at lower sites if budbreak persistently lagged. In assessing the importance of this work to tree planters, answers to several questions are needed. First, what is the magnitude of the variation in budbreak? Second, how long does the variation persist? Third and most important, what is the cause of the variation? I wish to answer the question of magnitude, partially answer the question of persistence, and explore with you some of the possible causes of the observed variation in budbreak.

The study design and layout are as follows: Acorns were collected from three parent trees at each of four elevations--1,400, 2,700, 3,800, and 4,600 feet above sea level. The three parent trees at each elevation were located

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within a few hundred feet of each other; the four collection sites, which were within 100 miles of each other, were near the cities of Morganton, Asheville, Franklin, and Canton, North Carolina. Acorns from the 12 parent trees were then planted in March 1971 at four elevations--1,500, 2,200, 3,500, and 5,500 feet above sea level.

By late April and early May, most of the acorns had germinated. In spring 1972, one year after the acorns were planted, we began keeping records of budbreak. The first bud broke on April 10, and we made regular checks thereafter until May 18 when the last bud broke. For the purposes of this study, a bud was considered broken when green could be seen by the naked eye on any part of the terminal or lateral buds.

By April 20, about half of the seedlings in the study had broken their buds, and a definite pattern of budbreak was beginning to develop. A few of the seedlings from the lower elevations had fully developed leaves, while most of the seedlings from higher elevations had not yet broken their buds. The effects of a frost or hard freeze would have been quite discriminatory, with the seedlings from the lower-elevation sources bearing the worst of it.

The percentage of budbreak on April 20 and the average date of budbreak by elevation of the seed sources are shown in table 1. These figures are averages for all four planting sites. The table indicates that, by April 20, almost all of the seedlings from the 1,400-foot elevation had begun budbreak while only a third or less of the seedlings from the 3,800- and 4,600-foot sources had broken dormancy. There was an 11-day difference between average dates of budbreak for the 1,400- and 4,600-foot sources.

Table 1.--The effect of elevation of seed source on the time of budbreak of red oak seedlings

Elevation of seed source (feet)	Budbreak by April 20 Percent	Average date of budbreak
1,400	80	April 19
2,700	65	April 21
3,800	30	April 26
4,600	15	April 30

A more complete breakdown of the data appears in table 2. It shows the average date of budbreak for each parent tree and each source by planting site. These data indicate relatively close agreement between the average dates of budbreak for parent trees from a given source at a given outplanting site. At the 1,500-foot outplanting site, for example, 17.8, 20.0, and 20.6 days elapsed

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Table 2.--Average time of budbreak by elevation of seed source and outplanting site

Elevation of outplant- ing site (feet)	Seed source at elevation of--															
	1,400 feet				2,700 feet				3,800 feet				4,600 feet			
	Tree 1	Tree 2	Tree 3	Avg.	Tree 1	Tree 2	Tree 3	Avg.	Tree 1	Tree 2	Tree 3	Avg.	Tree 1	Tree 2	Tree 3	Avg.
1,500	17.8	20.0	20.6	19.5	23.0	20.4	22.3	21.9	29.9	27.0	28.1	28.3	30.8	30.3	30.3	30.5
2,200	17.0	17.3	16.9	17.1	20.1	18.1	19.3	19.2	24.8	22.5	--	23.7	26.0	26.2	32.3	28.2
3,500	16.8	14.8	14.3	15.3	17.5	14.8	14.8	15.7	18.3	21.3	--	19.8	25.7	25.4	29.0	26.7
5,500	24.4	23.7	23.8	24.0	24.1	26.5	26.0	25.5	27.7	30.4	36.7	31.6	37.1	36.1	34.5	35.9

after April 1 before budbreak occurred in the seedlings from the three parent trees at the 1,400-foot elevation. At each outplanting site, the average spread of dates for budbreak between each of the four sources was 3 days.

There were also differences between the average dates of budbreak for the outplanting locations, with dates ranging from April 19 to April 29. The outstanding observation concerning the four locations is the consistent effect of seed source and parent tree. There was about an 11-day difference between dates of budbreak for low and high sources at each of the outplanting sites.

The data presented thus far show that we can expect differences in dates of budbreak to be associated with elevation of the seed source and also that budbreak will vary by outplanting site. What about persistence? How long will this effect last?

We have just completed taking the third-year data on budbreak and they have not been completely analyzed. The trends are about the same as the second year results. However, there does appear to be more variation within the three-tree sources.

Additional information on the longevity of the budbreak effect can be derived from observation of 8-year-old seedlings from three parent trees. The parent trees are located at elevations of 2,700, 3,500, and 4,800 feet above sea level, and the outplanting site is located at 2,200 feet. In each of the 8 years, budbreak for seedlings from the 4,800-foot source has lagged, ranging from 1 to 3 weeks behind the other two sources.

Thus, the effect of seed-source elevation on budbreak appears to be enduring. The longer the effect continues to be in evidence, the more important these study findings become, and the greater the need to determine the cause of the phenomenon.

One way to explore the cause and effect relationship between budbreak and seed source is to return to the classical choice between the effects of the environment and of heredity. Let us try to make a case for each possible cause.

First, we might attempt to prove that the environment is the primary cause for the observed differences in budbreak. Everyone is aware that the microclimate varies considerably between elevations. Light, temperature, humidity, rainfall, and winds will often be different at different altitudes. We expect colder temperatures and shorter growing seasons at the higher elevations. We can argue that the acorns are subjected to a different environment at each of these locales and that the environment preconditions the acorns to perform in certain ways. As proof of this argument, we can point out the generally close agreement between dates of budbreak for the seedlings from each set of three parent trees at the various outplanting sites (table 2). We could argue that it is not likely that the three parent trees in each set have the same parentage and that, consequently, the association must be due to effects of the environment at the source.

On the other hand, we can present an argument favoring heredity over environment. So far as we know, the four areas sampled have supported northern red oak for a long time--at least several generations. During this period, seedlings best adapted to the site would have the best chance of long-term survival. Thus, we should not be too surprised if the entire population of red oak trees on a mountaintop was proven to have a late-budding characteristic. Theoretically, this characteristic should be passed on through the offspring. In support of this theory, we can cite the same data that were used in the previous argument that environment is the primary cause of the observed differences in budbreak: the close agreement between dates of budbreak for the seedlings from each set of three parent trees at the various outplanting sites (table 2). Additional evidence tending to discredit the theory that environmental preconditioning determines budbreak is the effect of vernalization on red oak. Northern red oak acorns that have been exposed to cold treatment or stratified do germinate earlier and more uniformly than unstratified ones. Thus, those acorns collected at the higher elevation would have undergone considerable cold treatment prior to collection in October. Consequently, the environmental effect would tend to hasten budbreak, not retard it. It also seems that time would diminish any effect of the original environment after the acorns were outplanted elsewhere. Yet, seedlings 3 and 8 years old are continuing to manifest an association between elevation of the parent tree and time of budbreak.

After considering both arguments, I am unable to reach a decision as to the cause of the observed variation in budbreak of northern red oak. Perhaps the best course at this time is merely to accept the fact that there is an association between elevation of seed source and the time of budbreak and to reemphasize the practical implication of such an effect with the following example:

On April 25, 1972, a medium frost and a temperature of 26° F. occurred at the 1,500-foot outplanting site. On that date, many of the seedlings from the 1,400- and 2,700-foot sources had fully developed leaves and were visibly damaged by the frost. On the other hand, seedlings from the two higher sources were not nearly so well developed and they sustained no visible damage. If this combination of budbreak plus frost is repeated for several years, then the cumulative impact on the growth, and ultimately on the survival, of these seedlings will be considerable.

VARIATION IN HEIGHT GROWTH AND FLUSHING
OF NORTHERN RED OAK (QUERCUS RUBRA L.)

William R. Gall and Kingsley A. Taft, Jr.^{1/}

Abstract.--Forty-nine five-year-old Northern red oak open-pollinated families from six geographic sources were used to derive heritability estimates for height growth and date of bud break. Response to nitrogen fertilizer was positive for total height and number of flushes. Progenies from more southerly sources leafed out earlier than those of more northerly origin.

Additional keywords: Nitrogen, maternal effects, bud break, heritability, provenance, gain.

Although Northern red oak (Quercus rubra L.) is a fast-growing and desirable species, slow early growth has been a problem in artificial regeneration of the species. Kriebel and Thielges (1969) reviewed the literature on genetic work with Northern red oak and concluded that little information was available. Still, no published estimates of heritabilities have been presented.

Northern red oak has been shown to respond to application of nitrogen fertilizer (Farmer et al., 1970; Foster and Farmer, 1970), except when natural soil nitrogen is high (McComb, 1949). Date of bud break of Northern red oak progenies (McGee, 1970) is related to the altitude of the mother trees. Zasada and Zahner (1970) report that date of bud break is related to stage of vessel development in Northern red oak, so the variation in date of bud break associated with genetic and environmental factors may affect wood properties such as specific gravity.

This paper is a preliminary report on an experiment established by the Tennessee Valley Authority to determine inheritance patterns for, and the effect of fertilizer on, selected growth characteristics, such as height and date of bud break, in Northern red oak.

METHODS

Acorn collections in 1966 resulted in forty-nine open-pollinated families from six forest stands, or sources (Table 1). Seedlings were grown in three replications in the nursery for one year before outplanting on Jones Island in the Clinch River near Oak Ridge, Tennessee at a latitude of 35° 54' N. and an elevation of 760 feet. The soil was a very fine sandy loam, and the ground cover Kentucky 31 Tall Fescue, which was mowed periodically.

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Table 1.--Locations of seed sources, numbers of families from each, latitude, longitude and elevation in feet.

Source	No. of Families	Latitude	Longitude	Elevation
Ohio	8	40° 45'	81° 55'	960
Western Kentucky	5	36° 49'	88° 2'	500
Norris Lake	11	36° 20'	83° 57'	1300
Norris Dam	10	36° 12'	84° 5'	1100
Cumberland Plateau	10	35° 44'	85° 22'	1200
North Alabama	5	34° 31'	86° 57'	550

Twelve-seedling family plots were established in seven blocks. Half-sib families were randomized within each source, and sources were randomized within each block. Each plot consisted of two rows of six trees each, with nine feet between rows and four feet between trees within rows.

In May, 1971, six of these blocks were regrouped into three replications, each containing two blocks. One block in each of the three replications was selected at random and treated with 220 lbs. of nitrogen per acre by the application of 0.22 lbs. of ammonium nitrate per tree in a two-foot-diameter circle.

In 1970, 1971 and 1972, the first, third and fifth seedlings in each family plot were measured. Date of bud break was determined, as well as the number of flushes during each growing season. In addition, total heights of all seedlings were measured in 1968, 1969, 1970 and 1972.

The data were analyzed using a compact family block design, as described by Panse and Sukhatme (1954). This analysis was used because of time limitations; a more complex combined analysis will be conducted to obtain better heritability estimates.

The following model was used to analyze variation among sources:

<u>Source</u>	<u>d.f.</u>	<u>EMS</u>
Blocks	b-1	$\sigma_{BS}^2 + s\sigma_B^2$
Sources	s-1	$\sigma_{BS}^2 + b\sigma_S^2$
Blocks x Sources	(b-1)(s-1)	σ_{BS}^2

The following model was used to determine within source variation:

<u>Source</u>	<u>d.f.</u>	<u>EMS</u>
Blocks	b-1	$\sigma_W^2 + w\sigma_{BF}^2 + wf\sigma_B^2$
Families	f-1	$\sigma_W^2 + w\sigma_{BF}^2 + wb\sigma_F^2$
Blocks x Families	(b-1)(f-1)	$\sigma_W^2 + w\sigma_{BF}^2$
Within Plot	bf(w-1)	σ_W^2

The genetic component estimated was assumed, as in Namkoong *et al.*, (1965), to represent $\sigma_A^2 + \sigma_{AE}^2$, where σ_A^2 is the causal component due to additive inheritance and σ_{AE}^2 is that due to the interaction of additive inheritance with the environment. The estimates of heritability were computed in the following way:

$$h^2 = \frac{4\sigma_F^2}{\sigma_W^2 + \sigma_{BF}^2 + \sigma_F^2}.$$

RESULTS

Total Height

Table 2 demonstrates the outstanding superiority of the western Kentucky source with regard to total height. The Norris Dam source was equal in height to the western Kentucky source in the first year after outplanting. In the fifth year, the Norris Dam source was second by a wide margin to the western Kentucky source.

Table 2.--Total heights by source and year, in feet

Sources	1968	1969	1970	1972
Western Kentucky	1.68	2.43	3.31	5.22
Norris Dam	1.68	2.16	2.86	4.31
North Alabama	1.60	2.18	2.85	3.92
Ohio	1.27	1.72	2.38	3.36
Norris Lake	1.31	1.79	2.43	3.25
Cumberland Plateau	1.23	1.74	2.39	3.20

a/ The western Kentucky source is significantly different from four other sources at the 5% level.

In Figure 1, total height is plotted against latitude for each of the four years in which total height was measured. The curves are nearly horizontal with respect to latitude, indicating little relationship between latitude and total height. The differences among the sources are accentuated as the trees grow older. In Figure 2 total height is plotted against years after outplanting. Trees from different sources appear to have different growth rates.

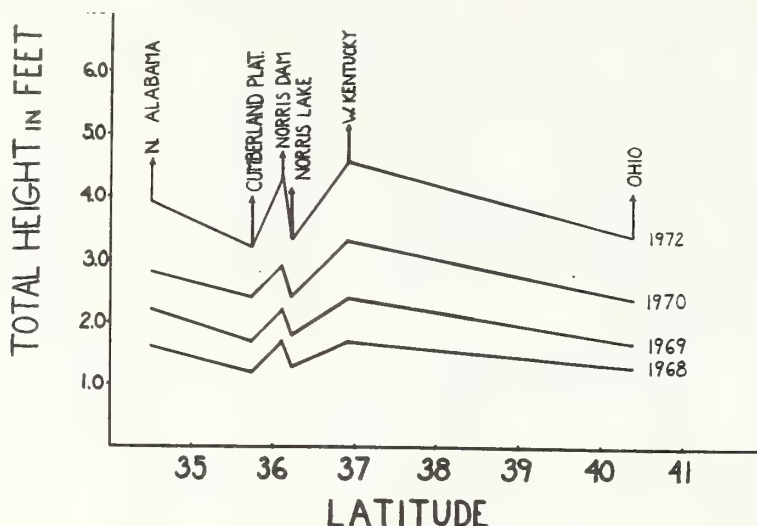


Figure 1.--Mean height of six seed sources at ages 1,2,3 and 5 as a function of latitude.

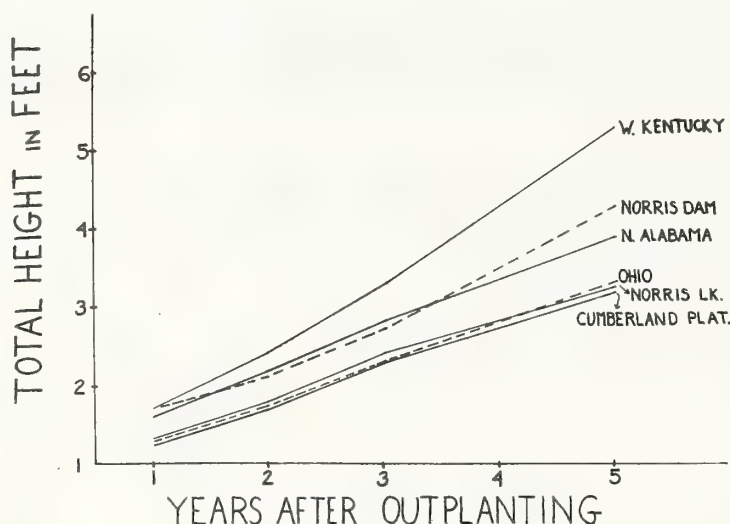


Figure 2.--Mean height of six seed sources measured following 1,2,3 and 5 growing seasons in the field.

Estimates of heritability of total height by source and year are presented in Table 3. In the first year after outplanting, two of the sources had estimates greater than unity. In the third year, two of the sources yielded estimates which were not significant at the .05 level of probability. In the fifth year, two of the sources had estimates which were negative but not significant at the .05 level. The estimates decrease in magnitude with increasing age of the trees and decrease at a decreasing rate after the first year.

Table 3.--Estimates of heritability of total height

Source	Heritability Estimates			
	1968	1969	1970	1972
Western Kentucky	.82	.40	.43	.38
Norris Dam	.29	.12	.10 n.s. ^{a)}	.23
North Alabama	.64	.12	.06 n.s.	.05 n.s.
Ohio	.57	.46	.39	.40
Norris Lake	1.30	.37	.23	-.03 n.s.
Cumberland Plateau	1.02	.35	.31	.25

^{a/} n.s. indicates the family component in the analysis of variance was not significant at the .05 level of probability.

Correlations between acorn weight and total height yielded coefficients of 0.32, 0.19, 0.16 and -0.027 for the first, second, third and fifth years respectively. The correlations were significant at the .05 level for the first three years, but not for the fifth year. Thus, the size of the correlation coefficient decreases with age.

Nitrogen Fertilizer

Effects of fertilizer on total height and number of flushes were analyzed using a compact family block design. The fertilizer effect was significant at the .05 level in increasing total height in 1972 and in increasing the number of flushes in 1971, the year of application of the fertilizer, but not in 1970 or 1972. The differences between fertilized and unfertilized trees are as follows:

	<u>#flushes 70</u>	<u>#flushes 71</u>	<u>#flushes 72</u>	<u>ht 72</u>
fertilized	1.24	2.04	1.19	4.6 ft.
unfertilized	1.31	1.31	1.43	3.7 ft.

Date of Bud Break

Date of bud break is presented, by source and year, in Table 4. The rank of the sources is the same in all three years in which measurements were taken. Three of the sources were not separated by Duncan's New Multiple Range Test.

Table 4.--Date of bud break, in days after March 31

Source	1970	1971	1972
North Alabama	22.3	25.3	21.2
Cumberland Plateau	24.9	29.6	26.1
Western Kentucky	25.0	29.8	26.2
Norris Dam	25.7	30.9	27.4
Norris Lake	27.8	33.5	31.0
Ohio	34.2	40.8	38.3

a/ Three dates connected with line are not significantly different at the 5 percent level.

Date of bud break is plotted against latitude in Figure 3. The date of bud break is generally earlier the more southerly the seed source, the western Kentucky source being the exception to the pattern.

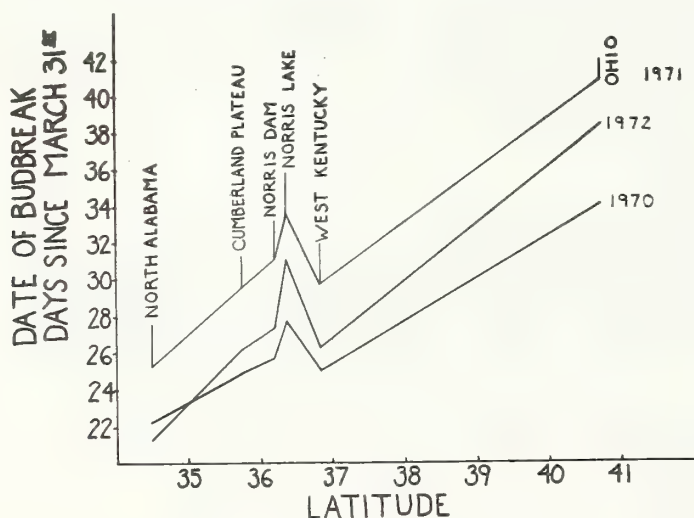


Figure 3.--Mean date of bud break of six seed sources for three years as a function of latitude.

Estimates of heritability of date of bud break (Table 5) are variable from year to year and from source to source. Five of the estimates are greater than unity, four of these being in two sources. Six estimates were derived from family components which were not significant at the .05 level of probability, including three for the Cumberland Plateau source. All three of the estimates for the Norris Lake source were equal to .36 and were derived from family components which were significant at the .05 level.

Table 5.--Estimates of heritability of date of bud break, by sources and years

Source	Heritability Estimates		
	1970	1971	1972
North Alabama	.68	1.33	1.78
Cumberland Plateau	.14 n.s. ^{a/}	.25 n.s.	.30 n.s.
Western Kentucky	1.01	.27 n.s.	.31 n.s.
Norris Dam	.52	1.38	1.14
Norris Lake	.36	.36	.36
Ohio	.35 n.s.	.70	.58

^{a/} n.s. indicates the family component in the analysis of variance was not significant at the .05 level of probability.

DISCUSSION

Total Height

The correlations between acorn weight and total height for the first three years imply that the high estimates of heritability of total height in the first year are primarily due to maternal effects. The decrease with age in both the size of the correlation coefficient and of the heritability estimates indicates that these maternal effects decrease with age, losing their effect in the fifth year. For this reason, the fifth year heritability estimates are probably the most reliable. The differential growth rates of the various sources become more apparent with age, indicating, too, the loss of influence of acorn weight.

The difference in fifth-year heritability estimates from source to source may be due to either or both of two possible causes. One of the possibilities is that the heritabilities, in fact, differ for different populations of the same species. The second is that the estimates vary in size because they are based on small numbers of families. Nevertheless, the variation in size of the estimates indicates that the variance components for family effects from different sources are heterogeneous and that, for this reason, the use of the compact family block design was justified.

Fertilizer

A positive response in total height to fertilizer application has been demonstrated previously. The increase in number of flushes in the season in which fertilizer was applied means that most of the increase in total height due to fertilizer probably occurs during that season. Further, it means that nitrogen increases total height by increasing the number of flushes, as well, perhaps, as by increasing the average length of each flush.

Date of Bud Break

A regression using 1972 total height as the dependent variable and the date of bud break and number of flushes in the same year as independent variables was significant at the .05 level of probability. The coefficient of determination, R^2 , was .13. Partial correlation coefficients for date of bud break and number of flushes were -0.32 and 0.22 respectively, both significant at the .05 level. The partial correlation coefficient for date of bud break indicates that trees which leaf out early grow taller. Thus, if one selects for late bud break in order to avoid frost injury, one may be selecting for low total height. An example of this situation may be seen in the case of the western Kentucky source, which is the tallest source, but which leafs out early relative to the latitude of its origin.

Some of the estimates of heritability of date of bud break are greater than unity. One possible explanation is that a large proportion of the progenies from some sources may be full sibs, since all the mother trees in each source are near each other. Another possibility is that the estimates represent the effects of two or more traits, which may interact. Response to daylength, for example, may be one trait, and response to temperature another. Thus, if warming-up occurs gradually in one year, the dates of bud break may be well differentiated within each source. If warming-up is delayed until late in the year and occurs suddenly, all the families of a given source may leaf out almost simultaneously.

Expected Gains

In proposing a selection scheme, it is suggested that one select for tallness in stands with high heritability estimates and discard tall families from stands with low heritability estimates. By selecting one tree from each twelve-tree plot and the twenty-five tallest of forty-nine families, with the exception of the preceding consideration, a seed orchard with an average of 49 trees per acre will remain. The expected gain in total height by this selection scheme is 20 percent at age 5.

CONCLUSIONS

Poor early height growth has been a problem in the artificial regeneration of Northern red oak. This problem may be ameliorated by the selection of families with rapid juvenile height growth. In addition, nitrogen fertilizer increases early height growth, as well as the number of flushes per season.

There was one outstanding seed source in this plantation. The western Kentucky source was the tallest after five years, as well as the fastest-growing and third in order of bud break.

Maternal effects, evidenced by correlations between acorn weight and total height, produced abnormally high estimates of heritability of height in the first year. Maternal effects decreased with increasing age for the first three years and disappeared by age five.

The sources leafed out in the same order in all three years. There was a shift in all the dates of bud break, however, from year to year. Estimates of heritability of date of bud break were high, but generally not constant. Several estimates were greater than one, possibly because of a high frequency of full sibs and/or the control of one response by two or more traits. It is suggested that planting stock may be selected for late bud break to avoid frost injury in more northerly areas and for early bud break to increase height growth in more southerly areas.

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CHILLING AND PHOTOPERIOD AFFECT DORMANCY
OF COTTONWOOD CUTTINGS

James W. Chandler and Bart A. Thielges^{1/}

Abstract.--Unrooted cuttings of 23 cottonwood clones were chilled at 1.6°C for periods of 0 to 90 days and planted in a greenhouse under normal and extended (16 hr.) photoperiods. The clones varied in flushing response to chilling treatment. Some required only 40 to 60 days of exposure to cold temperature to reach a point where additional chilling had no significant effect on reducing flushing time, while others continued to respond at 90 days. There were no distinct geographic trends associated with this variation. The extended photoperiod was effective in breaking bud dormancy only when the buds were not adequately chilled. Even short exposure to cold temperature (50 days) was sufficient to overcome any significant photoperiod's effect. These results suggest the possibility of using fast-growing northern selections of cottonwood with low "chilling requirements" for planting in the South.

Additional keywords: Populus deltoides, clones, flushing, selection.

A significant amount of genetic gain may be realized by introducing exotic species or geographic races of a native species under the assumption that the introduced plants will outperform the native stock. The success of these projects depends, of course, on knowledge of the interaction of the introduced genotypes with their new environment. One of the most critical factors is the adaptability of the introduced plant to the local climate.

The literature is filled with reports of unsuccessful projects, most commonly involving the testing or introduction of fast-growing southern selections of a species into a more northerly climate. The reason for these failures is usually obvious -- the trees fail to become dormant and are killed (or severely retarded) by cold temperatures.

The opposite situation, movement of plants in a southerly direction, should avoid many problems related to harsh environment. If soil and moisture conditions are adequate and susceptibility to disease and insects is low, selections which grow well in a native locale with a growing season of 150 days should grow even better when moved southward into a 300-day growing season. Unfortunately, these introductions are not always successful either, and there is a pronounced absence of many northern species in southern arboreta. Also, exotic ornamental and Christmas tree species which have been commercially successful in the North, such as Norway maple (Acer platanoides L.) and Scots pine (Pinus sylvestris L.), will not grow in many areas of the South. As in the movement of plants from southern latitudes to northern latitudes, one of the major problems concerns climate and dormancy. However, the properly timed induction of dormancy to escape freezing temperatures in the fall is not important here, but rather the failure of climatic conditions in the South to provide the stimulus to break dormancy in the spring.

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In a comprehensive review of the subject of dormancy in woody plants, Worrall and Mergen (1967) described winter bud dormancy as possessing two distinct phases: rest, an internal condition of the bud tissues which cannot be broken by exposing the plant to favorable environmental conditions, followed by a transition to quiescence, which may be broken by a return of favorable environmental conditions. The relative success of northern genotypes in southern climates depends upon the transition from the state of rest to quiescence.

Many greenhouse and laboratory investigations confirm that chilling and photoperiod are definitely factors affecting the breaking of rest in Populus species, but there has been some controversy over the relative importance of each factor (Pauley and Perry 1954, Wareing 1956, Van der Veen 1951). Studies of other hardwood species have shown that chilling time required for flushing varies from species to species and between geographic sources, but long photoperiods often prove to be suitable aids in restoring tree growth, especially when chilling is inadequate (Farmer 1968, Perry and Wang 1960).

To provide further information on the genetic variability in eastern cottonwood, a study was initiated to evaluate the effects of photoperiod and chilling on flushing and stimulating the rooting of stem cuttings of the species under greenhouse forcing conditions.

METHODS

One hundred cuttings were collected from each of 23 cottonwood clones of northern origins (Fig. 1) from the NC-51 Regional Cooperative provenance and progeny test growing at Wooster, Ohio. Ten chilling treatments, ranging from 0 to 90 days at 1.6°C, were applied to the cuttings. The initial "unchilled" treatment was established by planting 10 cuttings per clone, five in a normal photoperiod (9.5 to 10.5 hours) and five in a 16-hour photoperiod. Additional chilling treatments of 10 to 90 days were effected by removing 10 cuttings per clone from cold storage at (approximately) 10-day intervals and planting five each under each photoperiod.

Cuttings were checked for flushing and rooting three times per week and the dates of observed flushing and rooting were recorded for each cutting.

RESULTS

The analysis of variance for the flushing study revealed highly significant ($P < .01$) effects of clone, photoperiod, and chilling time, and the interactions of clone x chilling time and photoperiod x chilling time. The clone x photoperiod interaction was significant ($P < .05$) while the clone x photoperiod x chilling time interaction was highly significant. These significant responses and interactions were further evident after determination of the best-fitting empirical function (linear, quadratic, and/or cubic) for the flushing responses of each of the 23 clones as illustrated in Figure 2.

In general, regression analyses determined that all of these northern cottonwood clones required some degree of chilling to overcome rest. Increase in chilling time significantly reduced time until flushing for all clones up to a point at which further chilling had little or no effect. Additionally, as chilling time increased, the range of flushing time among ramets of a single clone decreased greatly.

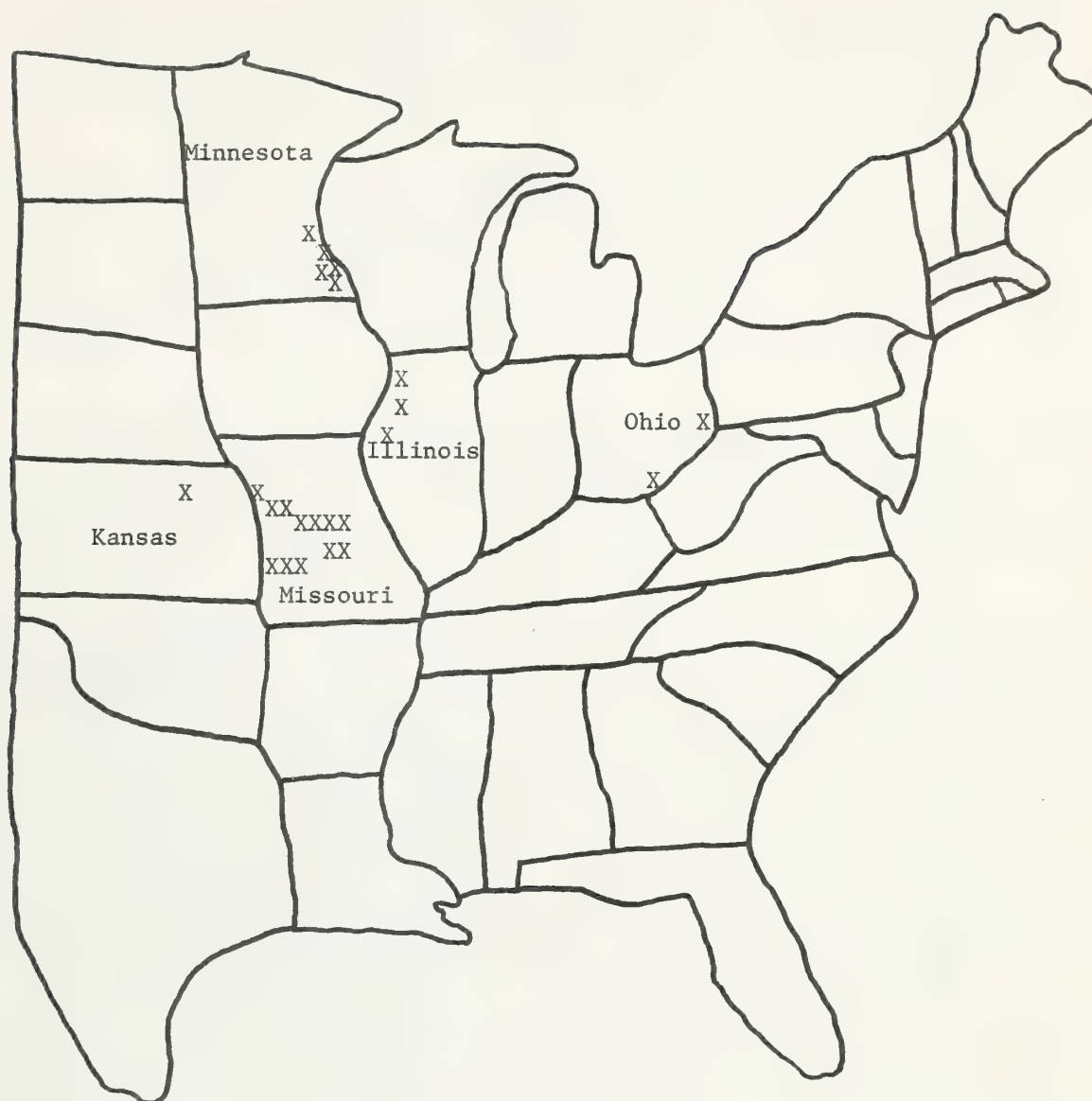


Figure 1. Location of sources of eastern cottonwood clones used in the study.

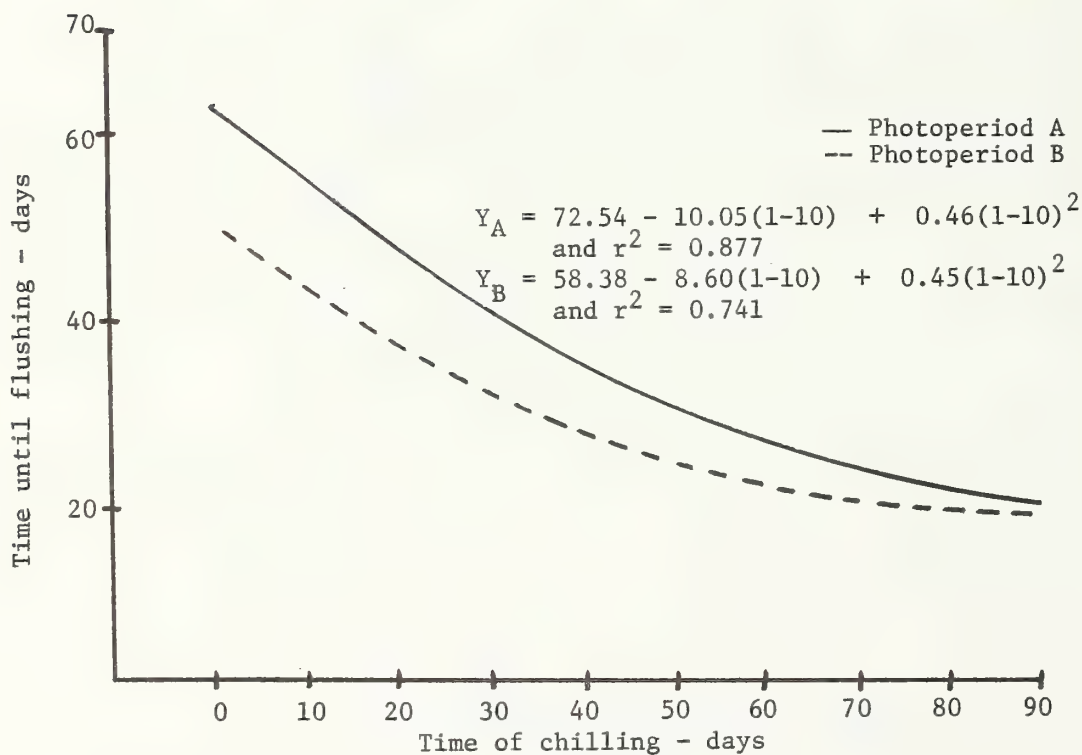
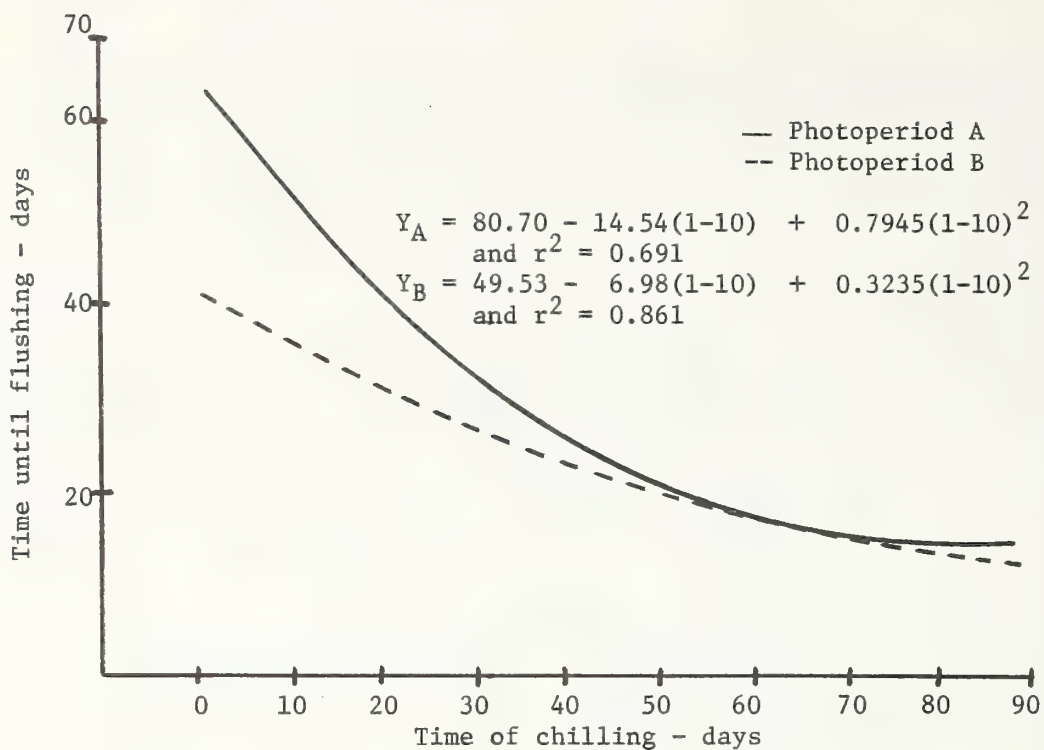


Figure 2. Comparison of the flushing responses of clones 218-2 (top) and 232-2 (bottom) as they were exposed to each photoperiod at various chilling times.

Although the flushing responses to chilling time varied among clones and there were also variations in the shape of the response curves between photoperiod treatments for certain clones, an important aspect of this study was the marked reduction in the effect of photoperiod on flushing time as chilling time increased. There was a significant positive response to the extended photoperiod in unchilled and inadequately chilled cuttings, but differences in flushing time became less pronounced as the chilling requirements of each clone were satisfied. These observations corroborate the findings of Worrall and Mergen (1967) who obtained similar results with Norway spruce (Picea abies L.) clones.

There was no evidence of a regular or clinal relationship between latitude of the seed source and response to chilling treatment in this study. Two factors may serve to explain this: (1) the clones utilized in this study are all of northern origin and the latitudinal range represented by the seed sources is rather narrow and (2) the parent trees for the NC-51 study were selected along the banks of major rivers to test the hypothesis of gene exchange by immigration from upstream populations. Significant downstream migration would certainly tend to mask any distinct geographical trends in a comparison of river-bottom populations.

The analysis of variance for rooting response revealed highly significant effects on time of rooting for clone, photoperiod, and chilling. All interactions were highly significant with the exception of the clone x photoperiod interaction which was non-significant. All of the clones showed a trend toward a decrease in time until rooting with increased chilling period, but this relationship was not as pronounced as that for flushing.

The 16-hour photoperiod was effective in reducing time until rooting in unchilled and inadequately chilled cuttings and, in many instances, the relationship was similar to that for flushing, i.e., a decrease in the effect of the extended photoperiod with increased chilling.

CONCLUSIONS

The following conclusions may be drawn from the results of this study:

1. A period of exposure to cold temperature is required to relieve the condition of rest in dormant buds of cottonwood from the northern portion of the range of the species. The longer this chilling period, the fewer days required for the buds to flush after exposure to warm temperatures.
2. There is genetic variation in flushing response to chilling. Some clones require only 40 to 60 days of exposure to cold temperature to reach a point where additional chilling has no significant effect on reducing the time until flushing, while others continue to respond at 90 days. No distinct geographic trends were associated with this variation. Apparently, northern stands of cottonwood are heterogeneous mixtures of heterozygous individuals with regard to chilling requirement.
3. An extended photoperiod is effective in breaking bud dormancy or rest only when the buds have not been adequately chilled. Even short exposures to cold temperatures (50 to 60 days in this experiment) are sufficient to overcome any significant effect of photoperiod. The results of this study confirm those of Worrall and Mergen (1967) with Norway spruce and Lavender et al. (1970) with Douglas-fir (Pseudotsuga menziesii Mirb. Franco) and

provide additional evidence that, in nature, completely chilled plants in northern latitudes initiate growth in the spring in response to warming temperature and not in response to photoperiod.

Based upon the results of this study, one of the most obvious applications is the use of some of these fast-growing northern clones in reforestation programs in the South. Many of the clones used in this experiment required only 50 to 60 days of chilling to begin growth in the spring and this requirement would be satisfied during a normal winter in many areas of the Lower Mississippi Valley. A test of these northern clones established in the L.S.U. Forestry nursery in the spring of 1972 has shown that all 23 clones flushed normally after exposure to a mild winter and that significant growth occurred. Field outplantings will be established as the nursery clones develop.

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GENETIC DIFFERENCES IN HEIGHT GROWTH AND SURVIVAL
OF COTTONWOOD FULL-SIB FAMILIES

D. T. Cooper^{1/} and W. K. Randall^{2/}

Abstract.--Sixteen full-sib families from crosses between four fast-growing female and four fast-growing male clones of cottonwood (Populus deltoides Bartr.) were clonally evaluated for 1 year in a replicated field test. Seedling size had no effect on clonal performance. Approximately 70 percent of the genetic variance for height and 20 percent of that for survival were additive. The cloned families survived better and grew taller than 12 Stoneville select clones included for comparison, but this difference may have been due to repeated propagation of the select clones.

Additional keywords: Populus deltoides, genetic variances, clonal propagation.

The experiment described here was designed to learn how the genetic superiority of fast-growing clones of Populus deltoides Bartr. can be exploited through breeding and selection. Four fast-growing female and four fast-growing male clones were crossed. The resulting 16 full-sib families plus 12 clones selected in the Stoneville cottonwood improvement program were evaluated in a replicated clonal test. Age-1 survival and height, two important characters in plantation establishment, were studied.

Additive and dominance components of variance were estimated. The relative sizes of these components indicate the probable effectiveness of selecting and breeding for genetic improvement. Effects of seedling size on clonal performance were determined, and performances of the full-sib families and of the Stoneville select clones were compared.

MATERIALS AND METHODS

The parents were four female and four male clones, including the five clones with most rapid diameter growth through age 6 from a study by Mohn and Randall (1971) and three of the 14 Stoneville select clones described by Mohn et al. (1970). All originated from within 50 miles of Stoneville, Mississippi. The parents were crossed in all possible combinations to produce 16 full-sib families. Seeds were planted in small peat pots in June 1970 and seedlings were transferred to the nursery at 12- by 40-inch spacing after 1 month. They were cut back to near ground level during February 1971 and allowed to regrow for 1 more year.

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From each of the 16 families, two groups of 12 seedlings were randomly chosen. Seedlings within each group were ranked and labelled according to height in January 1972. Eight 18-inch cuttings were prepared from each seedling.

Cuttings from 12 of the 14 Stoneville select clones described by Mohn et al. (1970) were also prepared. These had been cloned from seedlings 8 years earlier, cut back to ground level each year, and occasionally moved in the nursery by planting unrooted cuttings.

The material was arranged as two adjacent plantings, with two replications in each planting. Within each replication were 18 blocks, one for each of the 16 families and two for the Stoneville select clones. Blocks were randomly assigned. The two groups of clones from each family were placed in different plantings. Clones were randomized within each block.

The areas were planted on January 18-19, 1972, on a newly cleared Commerce silt loam riverfront site at Catfish Point, 30 miles north of Greenville, Mississippi.^{3/} Unrooted 18-inch cuttings were placed in freshly made subsoil trenches. Four-tree, row plots were planted at 12- by 12-foot spacing. Standard cultural practices for cottonwood as described by McKnight (1970) were used.

At the end of the first growing season survival was recorded and the height of each tree was measured to the nearest foot. Mean height was computed for each plot excluding trees which had obvious signs of mechanical injury.

The mean over all families was compared with the mean of the Stoneville select clones by analysis of variance. Clones from large seedlings were compared with clones from small seedlings by paired observation t test.

Components of variance were estimated from an analysis of the 16 families. The model was:

$$Y_{ijklm} = \mu + L_i + R_i(j) + P_k + M_\ell \\ + PM_{k\ell} + LP_{ik} + LM_{i\ell} + LPM_{ik\ell} \\ + \delta_{ijkl} + C_{kl(m)} + \epsilon_{ijklm}$$

Where: Y_{ijklm} = Observation

L_i = Location effect

^{3/} The site was provided and maintained by U.S. Gypsum Company.

$R_i(j)$ = Replication within location effect

P_k = Paternal parent effect

M_ℓ = Maternal parent effect

$PM_{k\ell}$ = Paternal x Maternal effect

LP_{ik} = Location by paternal effect

$LM_{i\ell}$ = Location by Maternal effect

$(LPM)_{ik\ell}$ = Location x Paternal x Maternal effect

$\delta_{ijk\ell}$ = Error associated with block variability within replicates

$C_{k\ell(m)}$ = Clones within full-sib family effect

$\epsilon_{ijk\ell}$ = Error associated with plot variability within blocks within replicates

The model is considered to be completely random with the parents representing a random sample from a finite population size. The form of the analysis is presented in table 1.

RESULTS AND DISCUSSION

Survival of most families was very high under environmental conditions which caused survival of the Stoneville select clones to be poor. Inadequate soil moisture during February and March appeared to be the cause of poor survival.

Mean survival for families was 78 percent and mean height was 14.1 feet (table 2). Family means for survival ranged from 41 to 91 percent. More than 100 of 384 clones had perfect survival. Family means for height ranged from 13.0 to 15.0 feet.

Performance of the 12 Stoneville select clones was significantly poorer than that of the families. Survival averaged only 43 percent and mean height, based on nine clones with adequate survival, was 13.6 feet (table 3). Only five of these clones, ST66, ST67, ST74, ST92, and ST109, are presently recommended for commercial use. Their mean survival was 63 percent and mean height was 13.3 feet.

Two of the 12 Stoneville select clones, ST66, and ST107, were also parents. Survival was 78 percent for ST66 but only 31 percent for ST107. Their cloned progeny averaged 82 and 79 percent survival, respectively. Another parent, ST81, was not clonally evaluated in this test but had poor survival in several other plantings. Two of the four families involving ST81 had very poor survival.

Table 1.--Form of the analysis for estimating variance components

Source of variation	Expected mean squares
Location (L)	
Replicates/L	
Paternal (P)	$\sigma_{\delta}^2 + j\sigma_c^2 + (1 - \frac{\ell}{L}) mj\sigma_{LPM}^2 + \ell mj\sigma_{LP}^2 + (1 - \frac{\ell}{L}) ijm\sigma_{PM}^2 + \ell ijm\sigma_P^2$
Maternal (M)	$\sigma_{\delta}^2 + j\sigma_c^2 + (1 - \frac{k}{K}) mj\sigma_{LPM}^2 + kmj\sigma_{LM}^2 + (1 - \frac{k}{K}) ijm\sigma_{PM}^2 + k ijm\sigma_M^2$
PXM	$\sigma_{\delta}^2 + j\sigma_c^2 + mj\sigma_{LPM}^2 + imj\sigma_{PM}^2$
LXP	$\sigma_{\delta}^2 + j\sigma_c^2 + (1 - \frac{\ell}{L}) mj\sigma_{LPM}^2 + \ell mj\sigma_{LP}^2$
LXM	$\sigma_{\delta}^2 + j\sigma_c^2 + (1 - \frac{k}{K}) mj\sigma_{LPM}^2 + kmj\sigma_{LM}^2$
LXPXM	$\sigma_{\delta}^2 + j\sigma_c^2 + mj\sigma_{LPM}^2$
Error I	σ_{δ}^2
Clones/Family/L	$\sigma_e^2 + j\sigma_c^2$
Error II	σ_e^2

Definition of symbols:

i = number of locations

j = number of replications within locations

k = number of randomly selected paternal parents

K = number of population of paternal parents

ℓ = number of randomly selected maternal parents

L = number in population of maternal parents

m = harmonic mean of clones within family.

Genetic interpretation of components of variance (Comstock and Robinson, 1952):

$$\sigma_{pm}^2 = \frac{1}{4}\sigma_{\text{Dominance}}^2$$

$$\sigma_m^2 = \frac{1}{4}\sigma^2_{\text{Additive}}$$

$$\sigma_p^2 = \frac{1}{4}\sigma^2_{\text{Additive}}$$

$$\sigma^2_{\text{Dominance}} = 4\sigma_{pm}^2$$

$$\sigma^2_{\text{Additive}} = 2(\sigma_p^2 + \sigma_m^2).$$

Table 2.--Survival and age-1 height of the 16 cottonwood crosses

Maternal parent	Paternal parent				
	DF16	DF43	ST66	ST107	Mean
SURVIVAL (PERCENT)					
DF1	79.7	91.2	86.5	83.9	85.3
DF12	75.0	81.8	89.6	89.1	83.9
DF47	78.1	72.4	76.0	81.8	77.1
ST81	82.8	42.2	76.6	62.0	65.9
Mean	78.9	71.9	82.2	79.2	78.0
HEIGHT (FEET)					
DF1	14.3	14.0	14.7	14.3	14.3
DF12	14.1	13.9	14.6	14.5	14.3
DF47	13.7	13.0	14.2	13.7	13.7
ST81	14.6	13.2	15.0	13.5	14.1
Mean	14.2	13.5	14.6	14.0	14.1

Based on these limited comparisons, there appears to be little relationship between survival of parents and progeny.

It is possible that at least part of the inferiority of the Stoneville select clones was not genetic. They had been propagated for 8 years in the nursery and may have lost some potential for survival and early vigor.

Seedling size did not significantly affect survival or age-1 height. Clones from large seedlings averaged 79 percent survival and 14 feet in height. Clones from small seedlings averaged 78 percent survival and 14 feet in height. It appears that selection for height among seedlings in a closely spaced nursery would be ineffective for improving clonal survival or age-1 height. At wider spacing, the situation may be different.

Table 3.--Survival and age-1 height
of the Stoneville select clones

Clone number	Survival (Percent)	Height (Feet)
ST63	15.6	--
ST66	78.1	14.0
ST67	43.8	13.1
ST70	3.1	--
ST71	71.9	13.8
ST72	31.3	14.5
ST74	59.4	13.5
ST91	28.1	13.4
ST92	59.4	12.9
ST107	31.3	14.2
ST109	75.0	13.1
ST124	21.9	--
Mean	43.2	13.6

Approximately 70 percent of the genotypic variance for height was additive, but only 18 percent of that for survival was additive (table 4). The errors associated with these estimates were not calculated, but both, and particularly that for survival, may have been large. A large error for survival is indicated by the discrepancy between clonal variance calculated from the variance within families and its expected value, $1/2$ additive genetic variance plus $3/4$, dominate genetic variance, estimated from the variance among families.

Genetic superiority due to additive genetic variance can be accumulated through repeated cycles of selection and intermating. Since 70 percent of the genetic variance for height appears to be additive, it should be possible to obtain considerable cumulative improvement. Since only 18 percent of the genetic variance for survival was additive, little improvement in this character can be accumulated. Most efforts to improve survival should be made in the final stages of improvement prior to commercial release of plants.

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Table 4.--Mean squares and estimates of variance components for height and survival

Source	Survival		Height		Component estimated	Survival	Ht
	df	MS	df	MS			
Location (L)	1	20573.75	1	88.6930			
Replicates/L	2	5664.88	2	17.3490			
Family (F)	15	6960.45	15	13.7583			
Paternal (P)	3	3648.81	3	34.2977	σ_P^2	1.07	0.0913
Maternal (M)	3	15037.71	3	19.7670	σ_M^2	42.13	.0889
PXM	9	5371.91	9	4.9090	σ_{MP}^2	98.10	.0348
LXF	15	1325.47	15	5.8284			
LXP	3	612.79	3	17.0593	σ_{LP}^2	-1.21	.1535
LXM	3	4024.25	3	2.9547	σ_{LM}^2	34.27	-.0045
LXPXM	9	663.43	9	3.0427	σ_{LPM}^2	-7.37	-.0351
Error I	30	657.93	30	3.1279	σ_δ^2	657.93	3.1279
Clones/F/L	352	544.14	336	1.2409	σ_c^2	91.15	.3492
Error II	352	361.85	336	.5425	σ_e^2	361.85	.5425
					σ_a^2	86.40	.3604
					σ_d^2	392.40	.1392
					$\sigma_G^2 = \sigma_a^2 + \sigma_d^2$	478.8	.4996
					$1/2\sigma_a^2 + 3/4\sigma_d^2$	337.50	.2846

FAMILY DIFFERENCES IN EARLY GROWTH AND WOOD SPECIFIC GRAVITY
OF AMERICAN SYCAMORE (*Platanus occidentalis* L.)

Charles D. Webb^{1/}, Roger P. Belanger^{2/}, and Robert G. McAlpine^{3/}

Abstract.--As part of a selection project to create strains for use under intensive culture, 64 wind-pollinated families were planted in an 8x8 triple lattice twice design using 4-tree square plots at a spacing of 4x4 feet. The plantation was clear-cut at the end of the fourth growing season to reveal family differences in sprout regrowth.

Growth for the first four years was good: plantation total height averaged 24 feet. Total dry weight of wood and bark approximated 10.6 tons per acre, or 2.60 tons per acre per year. Families exhibited significant differences in: dry weight per unit area, dry weight per tree, height, diameter at 1 foot, wood specific gravity, and seedling root collar diameter. The two best families were 50 to 60 percent greater than average for dry weight per tree and dry weight per unit area; the two poorest families were 30 to 35 percent poorer than average for the same traits.

Narrow-sense heritabilities were: seedling root collar diameter, 0.44; fourth year height, 0.27; fourth year diameter at 1 foot, 0.29; fourth year dry weight per tree, 0.31; and fourth year specific gravity, 0.78. These fractions should be corrected downward (multiply each by 0.56) to account for failures of the half-sib assumptions and for planting in only one environment. Genetic correlations between root collar diameter and traits measured at four years were: height, 0.31; diameter at 1 foot, 0.56; dry weight per tree, 0.47; and wood specific gravity, -0.15. Phenotypic correlations between specific gravity, and height, diameter, and dry weight per tree were approximately 0.3; genetic correlations between specific gravity and the same traits ranged between -0.12 and -0.25.

Estimated gains per unit of time from indirect selection on root collar diameter were slightly less than gains from direct selection on dry weight per tree at four years. If seedling densities in the nursery are kept uniform, indirect selection on seedling root collar diameter can be used to shorten the breeding cycle and to supplement direct selection at a later age.

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Additional keywords: Sycamore, heritability, indirect selection, genetic correlation, specific gravity.

If hardwoods are to be grown under intensive culture at short rotations (4 to 15 years) with mechanical harvesting and coppice regeneration, specially adapted strains will play an important role in the success of the concept. Phenotypic selection in natural stands probably will not be successful in this case. Instead, selection will be most effective in pedigreed test plantations that receive fertilization, weed control, and periodic harvesting to expose genetic differences in sprout regrowth characteristics. This report covers the quantitative genetic interpretation of the growth of one pedigreed test plantation from the nursery to the time of the first harvest, at the end of the fourth growing season.

METHODS

In January 1967, wind-pollinated seed were collected from 64 randomly-chosen sycamore trees growing in the Piedmont of Georgia in Clarke and Greene Counties. Seedlings were produced in an experimental nursery near Athens, Georgia, during the 1967 growing season. The nursery design was a randomized complete block design with four replications.

Soon after germination before intensive competition set in, each progeny was thinned back to 12 seedlings per square foot. As the season progressed, however, densities dropped slightly with increasing competition.

Before lifting, seedling tops were cut off at 4.5 inches above the root collar. Each seedling was identified with a tag of masking tape, and root collar diameter was recorded on each to the nearest 0.01 inch. In this way a nursery measurement was known for each tree in the field.

In March 1968, the seedlings were planted on a well-drained overflow river-bottom site in Greene County, Georgia. The site had been clear-cut and intensively site prepared two years before. An 8x8 triple lattice twice design (Cochran and Cox, 1957, plan 10.5) was used with 4-tree square plots and a spacing of 4x4 feet. Nursery replications were generally kept intact in establishing the field planting: nursery reps 1 and 2 went to field reps 1 and 2. However, nursery reps 3 and 4 were divided longitudinally; one-half of nursery rep. 3 went to field rep. 3, the other half to field rep. 4; one-half of nursery rep. 4 went to field rep. 5, the other half to field rep. 6.

The plantation received 1000 pounds per acre of 12-12-12 fertilizer in May of the first growing season, and 600 pounds per acre of ammonium nitrate in April at the start of the fourth growing season. During the first and second growing seasons, weeds were controlled by mowing.

A triple lattice twice design was used because selection was the objective; individual tree performance and family means were the quantities of primary interest. Early analyses indicated the lattice design gave little improvement in efficiency over a randomized block analysis. Therefore, a randomized block analysis of variance and covariance was used with expectations of mean squares and interpretations of variance components shown in Table 1. In a sense, the estimates of variance components are incidental, and must be qualified because

"...lattices...confound genetic and environmental differences among means..." (Dudley and Moll, 1969) and lattice designs are not the best for estimating variance components.

Table 1.--The form of the analyses of variance and construction of heritabilities and genetic correlations

Source	df	E(ms)
Replication	5	$\frac{\sigma_w^2}{k} + \sigma_{rf}^2 + f\sigma_r^2$
Family	63	$\frac{\sigma_w^2}{k} + \sigma_{rf}^2 + r\sigma_f^2$
RxF	<u>315</u>	$\frac{\sigma_w^2}{k} + \sigma_{rf}^2$
Total	383	
Within plot	993	$\frac{\sigma_w^2}{k}$

k = harmonic mean number of trees per plot = 3.4569

Assumption: half-sib family component $\sigma_f^2 \hat{=} 1/4 \sigma_A^2$

Narrow sense heritability:

$$h^2 = \frac{4\sigma_f^2}{\sigma_w^2 + \sigma_{rf}^2 + \sigma_f^2}$$

Genetic correlation among two traits, x & y

$$r_G = \frac{\sigma_{f_{xy}}}{\sqrt{(\sigma_{fx}^2)(\sigma_{fy}^2)}}$$

The assumptions underlying the analyses are routine and adequately outlined by Becker (1967) and Stonecypher et al. (1964). Wind-pollinated seed from a single parent tree are assumed to be half-sibs, and this has been subjected to some question (Namkoong, 1960). Furthermore, because the study samples only one planting environment, the estimates of additive variance admittedly carry an additive x environmental component (Namkoong, et al., 1966). Despite these qualifications, the variances deserve consideration.

Primary analyses of variance were calculated on the basis of plot averages because of variable numbers of trees surviving per plot. There were no missing plots; the harmonic mean number of trees per plot was 3.4569. Estimates of within-plot variance were obtained by a between-within analysis of all plots in the experiment. Standard errors of variance components, heritabilities, and genetic correlations were calculated according to Becker (1967).

At the end of the fourth growing season, the plantation was measured and clear-cut to a 3-inch stump. Each tree was weighed immediately to determine green weight to the nearest half-pound. Dry weight per tree was calculated two ways: (1) by converting green weight per tree to dry weight per tree using an assumed moisture content of 145 percent^{4/}:

$$\text{Dry weight} = \frac{\text{Green weight}}{2.45}$$

(2) by the regression equation^{5/}: $\hat{y} = -18.59650 + 28.72726 (D^2H)$

when \hat{y} = dry weight stem + branches + bark, without leaves

D = stump diameter at 6 inches

H = total height of tree.

Hence, the two methods of calculating dry weight per tree will be referred to as: "by percent" or "by regression."

Wood samples were collected at breast height when the plantation was harvested. Bark was removed, and disks were cut roughly 1-1/4 inches thick in the longitudinal direction. Green volume was determined by water displacement, and specific gravity expressed as oven dry weight/green volume.

RESULTS

Growth of the plantation over the first four years was good; total height averaged 24.3 feet. The total dry weight of the 0.56 acre plantation (wood and bark, but without leaves) approximated 10.6 tons per acre, or 2.6 tons per acre per year. Growth was slightly suppressed in parts of replications 2 and 3, due to an unforeseen and still unexplained environmental effect. However, the effects were not too serious.

F-tests of family effects showed significant differences for all traits, with the exception of first year diameter at 1 foot (Table 2). For the very important trait, total dry weight per plot, families exhibited a range of variation of considerable importance in an applied breeding program (Figure 1). The two best families produced 60 percent more dry matter than the plantation average; the two poorest families, 35 percent less than average.

^{4/} Personal communication with Alexander Clark, III, U.S.D.A. Forest Service, Southeastern Forest Experiment Station, Athens, Ga.

^{5/} Developed by J. Saucier, A. Clark, III, and R. G. McAlpine, U.S.D.A. Forest Service, Southeastern Forest Experiment Station, Athens, Ga.

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Table 2.--Summary of plantation means, family f-tests, heritabilities, and standard errors of heritability for each trait

Trait	Study mean		Family F-test	Herita- bility	Standard error of herita- bility ^{a/}
	English	Metric			
Root collar diameter	0.27 in.	6.96 mm	3.06**	0.44	0.12
First year					
Height	6.2 ft.	1.87 m	1.57**	0.17	0.02
Diameter at 1'	0.7 in.	1.80 cm	1.22 N.S.	0.07	0.07
Second year					
Height	13.1 ft.	3.98 m	1.49**	0.19	0.11
Diameter at 1'	1.4 in.	3.63 cm	1.57**	0.16	0.08
Height growth	6.9 ft.	2.10 m	1.57**	0.24	0.12
Third year					
Height	20.2 ft.	6.15 m	1.71**	0.25	0.11
Diameter at 1'	1.9 in.	4.78 cm	2.20**	0.26	0.09
Height growth	7.1 ft.	2.17 m	1.45*	0.15	0.09
Fourth year					
Height	24.3 ft.	7.42 m	2.11**	0.27	0.09
Diameter at 1'	2.2 in.	5.59 cm	2.60**	0.29	0.08
Height growth	4.2 ft.	1.27 m	2.45**	0.29	0.09
Specific gravity	0.412	0.412	5.68**	0.78	0.17
Dry weight/tree by regn	8.3 lb.	3.78 kg	2.66**	0.30	0.09
Dry weight/tree by percent	8.0 lb.	3.63 kg	2.86**	0.32	0.09
Total dry weight/plot	31.1 lb.	14.10 kg	2.39**	- <u>b/</u>	- <u>b/</u>

^{a/} From Becker, 1967

$$S.E.(h^2) = \frac{4 \sqrt{\text{Var. } \sigma_f^2}}{\sigma_w^2 + \sigma_{\text{rxf}}^2 + \sigma_f^2}$$

^{b/} No heritability calculated; no estimate of σ_w^2 possible.

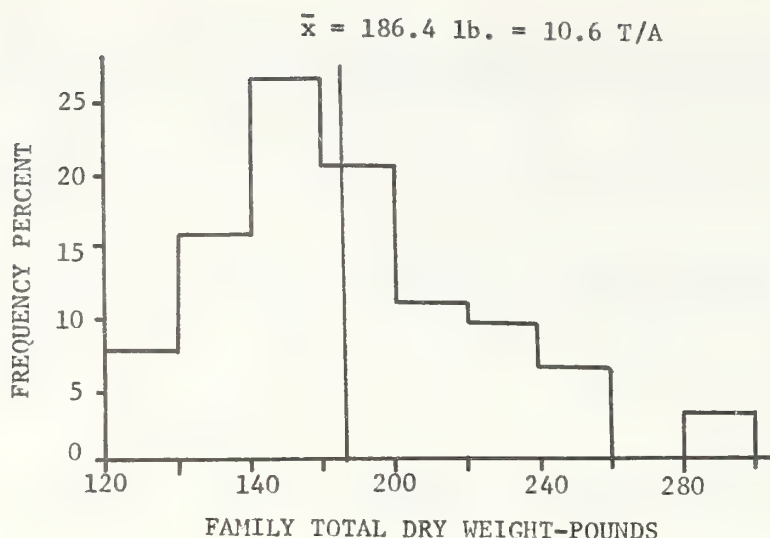


Figure 1.--Frequency distribution of family total dry weight (by regression) produced over all six replications in the plantation.

For specific gravity, individual trees varied between 0.34 and 0.48 (Figure 2). Family means for specific gravity ranged from 0.385 to 0.438. Heritability was high, 0.78, with a standard error of 0.17.

Heritabilities of height and diameter increased as the plantation grew older with the highest values occurring during the fourth growing season. Standard errors of heritabilities were considerably smaller than the heritabilities, and in only one case (first year diameter at 1 foot) did the standard error equal the heritability (Table 2).

Estimates of variance components for the most important traits are shown in Table 3.^{6/} Coefficients of variation of σ^2_f are reasonably small because of the numbers of families and replications in the plantation. Variance components for the two measures of dry weight per tree are essentially the same, with the exception of the family x rep. component: positive for dry weight by regression and negative for dry weight by percent. This may be an artifact created in estimating dry weight per tree by applying a single moisture content over the entire plantation.

For each trait, the phenotypic correlations with root collar diameter remained essentially constant up through four years (Table 4). However, the genetic correlations with root collar diameter started off high and decreased with increasing age. The genetic correlation for diameter at 1 foot may have stabilized around $0.56 \pm .09$ by three or four years of age, but may drop further for total height. Of particular interest for early selection is the genetic correlation of $0.47 \pm .08$ between root collar diameter and dry weight per tree.

^{6/} Complete sets of components of variance and covariance can be obtained at the Forestry Sciences Laboratory, Athens, Ga. 30602, from the Physiology and Culture of Piedmont Hardwoods Project.

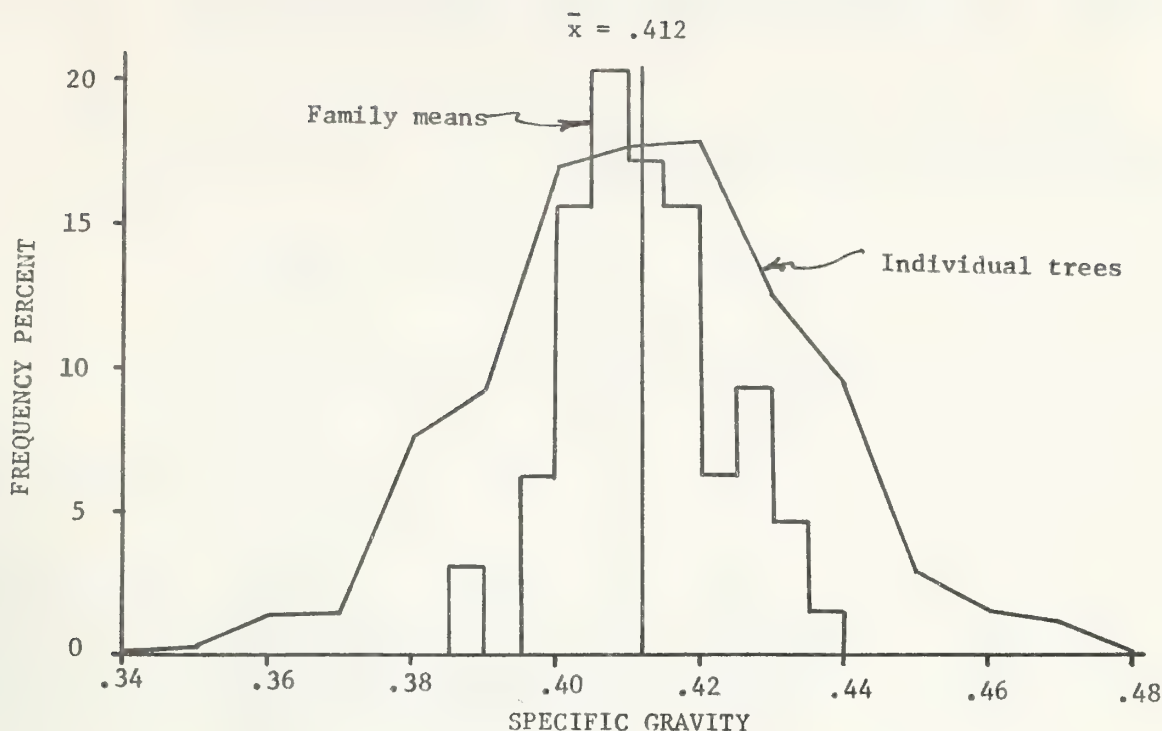


Figure 2.--Frequency distributions of wood specific gravities of individual trees and of family means.

The genotypic and phenotypic correlations among fourth year traits are summarized in Table 5. The phenotypic correlations between growth measurements and specific gravity were positive and approximately 0.3. However, genetic correlations between growth measurements and specific gravity were negative, ranging between -0.12 to -0.25.

The genotypic and phenotypic correlations among height growth during each growing season vary considerably by both sign and magnitude and do not show any clear patterns (Table 6).

DISCUSSION

The heritability fractions reported here (Table 2) probably should be considered as estimates of the upper limits of the fractions that could be realized in an applied breeding and planting program. Were the true sib-relationships known for each family, instead of the half-sib assumption that $\sigma_f^2 \hat{=} 1/4\sigma_A^2$, a mixed-sib assumption of $\sigma_f^2 \hat{=} 1/3\sigma_A^2$ might be more appropriate, according to recent calculations by Squillace^{7/}. To account for this qualification, the

^{7/} Personal communication with Dr. A. E. Squillace, Chief Plant Geneticist, USDA Forest Service, Southeastern Forest Experiment Station, Olustee, Florida.

Table 3.---Estimates of variance components of seedling root collar diameter and traits measured at 4 years of age

Trait	Replication σ^2_r	Family σ^2_f	Fam. x Rep. σ^2_{fr}	Within plot σ^2_w	CV σ^2_f
	Nursery				Percent
Root collar diameter	0.000553	0.000575	0.000451	0.004210	26.3
	End of fourth growing season				
Height	1.161161	0.803238	1.705860	9.116149	34.1
Diameter at 1'	0.007029	0.021311	0.001264	0.271865	28.9
Dry weight per tree-regn.	0.858775	1.751527	0.288256	20.939570	28.5
Dry weight per tree-%	0.854042	1.645532	-0.229068	19.159383	27.3
Specific gravity	-0.00000680	0.00009378	0.00001219	0.00037371	21.4

Table 4.--Genotypic and phenotypic correlations between root collar diameter in the nursery and traits measured later in the field

Trait		Genotypic correlation	Phenotypic correlation
First year	Height	0.61	0.36
	Diameter at 1'	0.98	0.32
Second year	Height	0.45	0.32
	Diameter at 1'	0.63	0.36
	Height growth	0.16	0.18
Third year	Height	0.38	0.32
	Diameter at 1'	0.55	0.38
	Height growth	0.26	0.21
Fourth year	Height	0.31	0.35
	Diameter at 1'	0.56	0.38
	Height growth	0.08	0.19
	Dry weight/tree-regn.	0.46	0.38
	Dry weight/tree-%	0.47	0.43
	Specific gravity	-0.15	0.08

Table 5.--Genotypic and phenotypic correlations among traits determined at end of fourth growing season

Trait	Diameter at 1'	Dry weight per tree		Specific gravity
		by regn.	by %	
Height	0.83	0.87	0.91	-0.12
	<u>0.84^{a/}</u>	<u>0.83</u>	<u>0.83</u>	<u>0.30</u>
Diameter at 1'		1.00	0.97	-0.25
		<u>0.97</u>	<u>0.93</u>	<u>0.30</u>
Dry weight per tree-by regn.				-0.20
				<u>0.28</u>
Dry weight per tree-by %				-0.21
				<u>0.28</u>

^{a/} Phenotypic correlation underlined.

Table 6.--Genotypic and phenotypic correlations among height growth during each growing season

Trait	Second year Height growth	Third year Height growth	Fourth year Height growth
First year height ^{a/}	0.32 <u>0.38^{b/}</u>	0.93 <u>0.31</u>	0.18 <u>-0.24</u>
Second year height growth		0.88 <u>0.50</u>	0.01 <u>-0.06</u>
Third year height growth			0.31 <u>0.07</u>

a/ Since seedlings were topped 4.5 inches above the root collar before planting, first year height was in essence height growth during the first growing season.

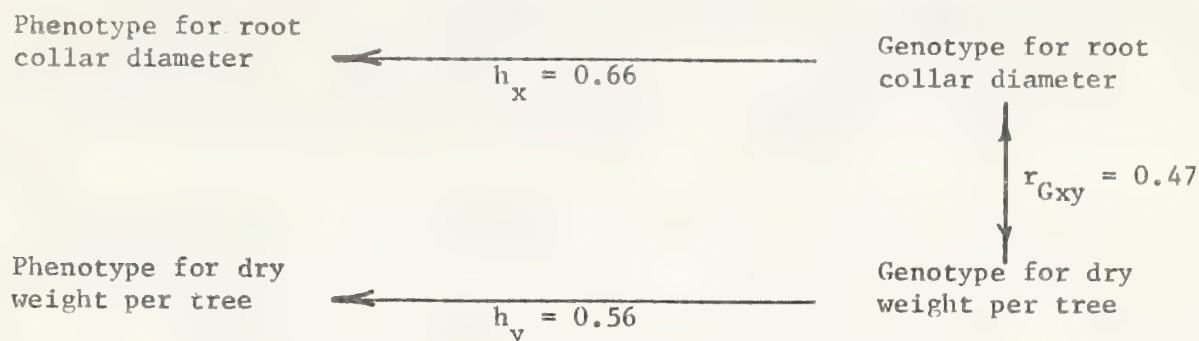
b/ Phenotypic correlation underlined.

heritabilities listed in Table 2 should be reduced by 25 percent (i.e., multiply by .75). Furthermore, because only one planting environment was sampled, the σ^2_A components of the heritability fractions include an additive x environmental component, σ^2_{AE} (Namkoong, et al., 1966). Therefore, the corrected heritabilities should again be corrected downward, possibly by another 25 percent (again multiply by .75). Accounting for both corrections, heritability of height would be reduced to 0.15, diameter to 0.16, dry weight per tree to 0.17, and specific gravity to 0.44. These qualifications must be borne in mind in the discussions to follow. While they affect the size of the heritabilities, they have little effect on the general conclusions that are attempted.

While the absolute size of the heritabilities may be subject to some question, the increases in relative size for height and diameter with age are in a reasonable direction (Table 2). The family components for both total height and diameter increased with age probably as a response to the intensive competition that developed at a spacing of 4x4 feet. In such a case, "the big get bigger and the small get smaller."

Of particular interest in this study are the genetic correlations between seedling root collar diameter in the nursery and later growth in the field (Table 4). Juvenile-mature correlations have received considerable interest in forest genetics, but few definitive results are available. These data represent the first stages of a developing juvenile-mature correlation.

By careful documentation during planting, it has been possible to show that a sufficiently strong genetic correlation exists to reward indirect selection on root collar diameter to increase dry weight per tree. Using path coefficient methods of Sewall Wright, recently outlined by Franklin et al. (1970), the following paths can be established:



where: h_x = square root of heritability of root collar diameter
 h_y = square root of heritability of dry weight per tree
 r_{Gxy} = genetic correlation between root collar diameter and dry weight per tree at age four years.

The gains in dry weight per tree from indirect selection on root collar diameter are approximated by:

$$\Delta_{G_{ind}} \hat{=} (h_x r_G h_y) \sigma_y i \hat{=} 1.648 \text{ lb.}$$

where: σ_y = 4.6 lb. = phenotypic standard deviation of dry weight per tree
 i = 2.063 = selection intensity for upper 5 percent

The gains from direct selection on dry weight per tree in the test plantation are approximated by:

$$\Delta_{G_{ind}} \hat{=} h_y^2 \sigma_y i \hat{=} 2.942 \text{ lb.}$$

where: h_y^2 = heritability of dry weight per tree
 σ_y , i defined above.

To compare gains from each method, they must be expressed as gain per unit time. In this case, gains should be divided by the number of years required to complete a breeding cycle, i.e., to go from mature seed through selection and recombination to mature seed. Here it will be assumed that a total of eight years will be required to propagate a selection, bring a ramet to sexual maturity, control pollinate, and mature seed. For indirect selection in the nursery, the cycle length is: 1 year, nursery + 8 years to seed = 9 years. For direct selection, the cycle length is: 1 year, nursery + 4 years, test plantation + 8 years to seed = 13 years. Gains per unit time for each selection method are:

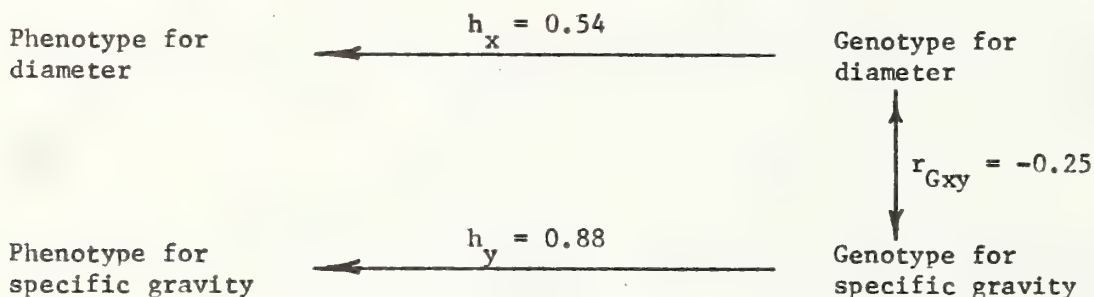
$$\text{indirect} = 1.648/9 = 0.1832 \text{ lb./year}$$

$$\text{direct} = 2.942/13 = 0.2263 \text{ lb./year}$$

If eight years are required to propagate and recombine, direct selection is clearly superior to indirect selection. If the propagation and recombination phases could be shortened to four years by growth hormones and other cultural measures, gains would be divided by four and seven years for indirect and direct selection respectively, and the gains per unit time would become almost equal.

There is a practical limit to how much the existing data can be manipulated. However, it is safe to conclude that, if the genetic correlation of 0.47 between root collar diameter and dry weight per tree does not decrease too much with increasing age, indirect selection on root collar diameter can be used to supplement, but not replace, direct selection at a later age in an effort to shorten the length of the breeding cycle.

The method of path coefficients can be used also to examine the impact of direct selection for growth on wood specific gravity. This path defines the impact of selecting for diameter:



where: h_x = square root of heritability of diameter

h_y = square root of heritability of specific gravity

r_{Gxy} = genetic correlation between diameter and specific gravity.

Change in specific gravity is calculated:

$$\Delta_{SG} \hat{=} (h_x r_G h_y) \sigma_y i$$

where $\sigma_y = .021902$ = phenotypic standard deviation of specific gravity

i = selection intensity.

The correlated decrease in specific gravity $\Delta_{S.G.}$, summarized in Table 8 for three intensities of selection, does not appear to be severe through one cycle of selection. These data suggest that the correlated negative response in specific gravity will probably be negligible in comparison to the increases in dry matter yield achieved by selection on height and diameter.

Table 8.--The correlated response in specific gravity caused by selection for diameter

<u>Selection intensity</u> Percent i		Correlated response $\Delta_{S.G.}$	New population average = $0.412 + \Delta_{S.G.}$
1	2.665	-0.008	.404
5	2.063	-0.006	.406
10	1.755	-0.005	.407

For two-year-old wind-pollinated progeny of cottonwood, Farmer (1970) found small genetic and phenotypic correlations for diameter x specific gravity, but with signs opposite from those reported here for sycamore. Farmer (1970) dismissed these correlations as being too low to have practical significance. Stonecypher et al. (1964) found negative genetic correlations for diameter x specific gravity in two- and three-year-old loblolly pines. However, Stonecypher et al. (1973) will report 10-year analyses of this same loblolly population showed the genetic correlations had turned strongly positive for specific gravity x volume: $r_G = +.36$, $r_P = +.28$. It is possible that in sycamore the genetic correlation between^P growth and specific gravity may become positive with increasing age. However, in programs breeding for short rotations, the effects should be closely monitored, and selection should favor both high specific gravity and rapid growth rate to achieve the maximum increase in wood substance production.

While this plantation samples only one planting environment, growth during each year samples a different "micro environment." Intensity of competition is changing; roots are exploring an increasing volume of soil; rainfall patterns vary from year to year; the effects of early fertilization are wearing off, and new fertilization was applied at the start of the fourth growing season. For these reasons, it is little wonder that the genetic and phenotypic correlations among height growth during each season are erratic in magnitude and sign (Table 6). First year results of this plantation and a companion plantation in a different environment suggested the existence of a genotype x environment interaction. These erratic correlations for height growth are probably also due to genotype x environment interactions. All this points to the necessity of establishing pedigreed test plantations in different environments to account for the genotype x environment interaction in the selection process.

What of importance to an applied breeding program can be inferred from the results and experiences gained from this single plantation, of a single population sample, of "half-sib families," once the qualifications of Namkoong (1966), Namkoong et al. (1966), and Dudley and Moll (1969) are accepted?

1. There is a sufficient supply of additive genetic variability in growth, dry matter yield, and wood specific gravity to reward a breeding program in sycamore. By using proper nursery techniques and field plantings designed to enhance combined individual plus family selection in a recurrent selection and breeding program, gains in dry weight per tree of 5 to 15 percent should be achieved each generation, at least for a few generations.
2. To be most effective, selection should be practiced in pedigreed test plantations established in at least two, preferably more, planting locations. Test designs should be chosen to facilitate selection on highly variable sites. If operational procedures are expected to call for fertilization, weed control, and coppicing, test plantations should be treated accordingly.
3. A base population can be developed by collecting wind-pollinated seed of better than average phenotypes (i.e. mild selection) from local populations as well as populations to the north and south of the intended planting environment.
4. Maintain the family identity of as many wind-pollinated families as possible. Fewer than 50 families would be considered too small a base population for a recurrent breeding program.
5. In the progeny test nursery, religiously maintain a uniform density from one progeny to the next. Failure to do so will confound early growth comparisons for a number of years. Seedlings should enter the intense competitive stage at densities of 6 to 8 seedlings per square foot.
6. If more families are available at the end of the nursery season than can be planted in the field, reject those families having the smallest root collar diameters.
7. Because sycamore seedlings usually die back from the top to varying degrees after field planting, genetic differences in early growth will be revealed better if tops of the seedlings are cut off in the nursery bed or at time of lifting, 4 to 8 inches above the root collar.
8. Indirect selection on root collar diameter can be used to supplement direct selection at a later age, provided seedling densities have been maintained uniformly enough in the nursery. Combined individual and family selection can be applied at the end of the nursery season to select potential breeding candidates. Propagation and sexual aging of these candidates can begin immediately by rooting the tops of the seedlings as dormant cuttings (Schmitt and Webb, 1971). Once rooted, these can be set out in a clone bank for future breeding work--probably sooner than breeding can begin on trees chosen by direct selection.

ACKNOWLEDGEMENT

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EARLY DEVELOPMENT OF OPEN-POLLINATED SWEETGUM PROGENIES

Carl Mohn and Dan Schmitt¹

Abstract.--Data on 6-year-old sweetgum progenies planted on two sites in Mississippi indicate moderate heritabilities for height and diameter. Relatively large family-location interactions for height and diameter suggest that most sweetgum selections should be planted within limited zones. Since number of branches on the lower bole was not under strong genetic control, selection to minimize number of branches would be ineffective.

Additional keywords: Liquidambar styraciflua, heritability, genetic variability.

Because sweetgum (Liquidambar styraciflua L.) is a prime candidate for intensive hardwood management in the South, tests to determine its genetic variability are underway. This paper summarizes measurements made in two such tests 6 years after planting. The data supplement Wilcox's (1970) report on survival, growth, phenology, and crown development through the end of the third growing season.

MATERIALS AND METHODS

In 1962 we planted sweetgum seedlings from 40 parent trees representing a wide range of phenotypes and sites in south Mississippi. Two plantations were established with 1-0 seedlings. The planting sites were about 200 miles apart; one was on the Harrison Experimental Forest (HEF) near Gulfport, Mississippi (31°N); and the other, on the Delta Experimental Forest (DEF) near Greenville, Mississippi (33°N). The HEF plantation is on a sandy, well-drained loam; and the DEF planting is on a fertile, poorly-drained clay.

Trees were spaced 12 feet apart in a randomized complete-block design with five blocks at each site. Each plot contained a four-tree row from a single family.

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During the 1968-69 dormant season, 6 years after planting, we collected the following data from all surviving trees: total height to the nearest 0.1 foot, d.b.h. to the nearest 0.1 inch, number of live and dead branches between 3 and 4.5 feet, and base diameter to the nearest 0.1 inch of the largest branch in this segment of the bole. Mortality was 7 percent in the HEF and 17 percent in the DEF. Dead trees were well distributed among plots, and results probably were not influenced by the pattern of mortality.

Heights, tree diameters, branch diameters, and numbers of branches were examined by analysis of variance using plot means. Within-plot variances were estimated from individual-tree data on one-fifth of the plots; and heritabilities were estimated from these values. We first analyzed the data separately for each planting. When significant (0.05 level) differences were found for a trait in both plantations, we performed combined analyses for that trait. Components and standard errors were estimated with techniques described by Becker (1967). Independence of family and percentage of living branches were tested by chi-square (Steel and Torrie 1960). Relationships between means of different traits in the same plantation and the same traits in the two plantations were examined using Spearman's coefficient of rank correlation (Steel and Torrie 1960).

Table 1.--Growth and branch characteristics of a sweetgum progeny test on two sites

Characteristic	Site	
	Harrison Exp. Forest	Delta Exp. Forest
Sixth-year height (feet)		
Mean	17.1	11.6
Range family means	14.3 - 19.5	10.2 - 12.9
Sixth-year diameter (inches)		
Mean	2.2	1.4
Range family means	1.56 - 2.55	1.1 - 1.6
Number of branches 3 to 4½ feet		
Mean	7.5	9.1
Range family means	6.3 - 8.6	7.8 - 10.7
Percent branches living 3 to 4½ feet		
Mean	78	93
Range family means	46 - 98	85 - 100
Diameter largest branch 3 to 4½ feet (inches)		
Mean	.38	.46
Range family means	.33 - .44	.39 - .57

Table 2.--Variance components and heritability estimates for characteristics showing significant differences at age 6

Characteristic and Plantation	Component				h^2^a
	family (σ_f^2)	experimental error (σ_{rf}^2)	within plot (σ_w^2)	location x family (σ_{fl}^2)	
Total height					
DEF	.043	.294	.736	----	.16 ± .13
HEF	.282	.199	3.503	----	.28 ± .11
combined	.069	.108	2.586	.110	.10 ± .08
Diameter					
DEF	.0027	.0090	.0297	----	.26 ± .14
HEF	.0069	.0119	.0757	----	.29 ± .13
combined	.0028	.0090	.0584	.0023	.15 ± .10
No. branches					
HEF	.032	.001	1.343	----	.09 ± .07

a

$$h^2 = \frac{4 \sigma_f^2}{\sigma_f^2 + \sigma_{rf}^2 + \sigma_w^2} \quad (\text{individual plantations})$$

$$h^2 = \frac{4 \sigma_f^2}{\sigma_f^2 + \sigma_{rf}^2 + \sigma_{fl}^2 + \sigma_w^2} \quad (\text{combined plantations})$$

RESULTS AND DISCUSSION

Differences among families for sixth-year height and diameter were significant in both plantations (table 1), and the family component of total variation was substantial (table 2). Heritabilities for height were larger in the HEF plantation than in the DEF (.28 vs .16), but heritabilities for diameter were essentially equal in the two plantings (.29 HEF vs .26 DEF). Genetic control of these two characteristics is strong enough in both plantations to make selection effective. As expected, the two traits are strongly correlated; rank correlations of height and diameter means were .80 in the HEF planting and .82 in the DEF. Because of this close relationship between height and diameter, volume increases should be easy to obtain.

Differences in growth between the two plantations were substantial, reflecting the effects of site and location (table 1). Height growth was faster in the HEF during the first two growing seasons but was essentially the same in both plantations in the third year. Thereafter, the HEF's height growth again exceeded the DEF's. By the sixth year, mean height in the HEF plantation was 5.5 feet greater and mean diameter 0.8 inches larger than in the DEF.

The combined analyses for sixth-year height and diameter showed significant family-location variance components. The ratio of the interaction component to the family component indicates the relative importance of the former. The ratios for available height and diameter were:

<u>Years after planting</u>	<u>Ratio of family-location to family for</u>	
	<u>Height</u>	<u>Diameter</u>
1	.45	--
2	.32	--
3	.69	--
6	1.59	.82

The relative magnitude of the family-location interaction appears to be increasing over time for height. This trend is paralleled by a reduction over time in Spearman's rank correlation coefficients for mean family heights in the two plantations. These coefficients were significant (0.05 level) every year, but the value decreased from .54 in year 1 to .35 in year 6. Even more striking is the complete lack of correlation between family mean growth in the two plantations after the third year ($r_s = -.01$). These data suggest that future heights of families in the two plantations may be completely unrelated. Values needed to examine trends in diameters are not available, but sixth-year interaction components were large relative to family variation.

Squillace (1970) suggests that interactions between genotypes and environments are common when trees are grown on widely separated sites. In this experiment the small number of sites prevented determination of patterns or trends, and no biological explanation for the interaction can be offered. However, the existence of strong family-location interactions, regardless of their origin, has implication for improvement work. The reduced heritability estimates obtained by combining data from the two sites suggests a potential loss in effectiveness of selection if materials are used over a wide geographic area. The sweetgum breeder should plant improved material in bioclimatic areas similar to those supporting the original selections.

The average DEF tree had more branches, larger branches, and a higher percentage of living branches than the typical HEF tree. On the other hand, genetic control of branch characteristics seemed slight. Branch size did not vary significantly among families in either plantation. Number and proportion of living branches were also unrelated to family in the DEF planting.

In the HEF, family influenced number of branches somewhat, but the heritability estimate was only $.09 \pm .07$ (table 2). The proportion of living branches was also significantly related to family in the HEF planting, where trees were taller and more branch mortality had occurred. Family means for this trait ranged from 46 to 98 percent, and there was a significant positive correlation between family means for branch mortality and for height ($r = .32$). Since height affects branch mortality, any conclusions regarding the genetic control of the latter characteristic are tenuous.

In brief, the relatively small variation among families in the HEF and the lack of variation among families in the DEF do not suggest strong genetic control of branch characteristics or indicate that selection to influence such characteristics would be particularly effective.

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BLACK WALNUT PROGENY AND CLONAL TESTS AT PURDUE UNIVERSITY

Walter F. Beineke and Charles J. Masters ^{1/}

Abstract.--The genetic improvement of Indiana black walnut at Purdue University has progressed along two important fronts: (1) progeny testing of superior tree selections, and (2) clonal development and testing of these selections.

Prior to clone bank flowering, half-sib testing of superior individuals comprised the bulk of our work. Nursery, one, two, and three-year-old outplanting results have shown surprisingly high inheritance, and genotypic and phenotypic correlations on growth parameters. In addition, family performance compared with the commercial check has been outstanding.

At this time the clonal program utilizes 106 grafted clones. Analysis of variance and heritability estimates on foliation date, defoliation date, height, diameter, sweep, crook, branch angle, branch number, and anthracnose resistance show striking differences.

Additional keywords: *Juglans nigra* L., heritability, height and diameter, foliation, form, half-sib, hardwood genetics.

The genetic improvement of black walnut (*Juglans nigra* L.) at Purdue University has progressed to the stage that significant information on inheritance and variation in certain traits from half-sib progeny and clonal tests is available. The program began in 1967 with a few black walnut selections of dubious quality. Today, 106 selections are included in the program. Selections are rated on a point system for straightness, apical dominance, and growth rate based on a modified system from that reported by Beineke and Lowe (1969). All selections are preserved by grafting in a clone bank at Purdue-Shidler Forest (Lowe and Beineke, 1969). Application of the clonal seed orchard approach is in the initial stages of development by the Indiana Division of Forestry and has many advantages over half-sib seedling orchards (Masters and Beineke, 1972).

HALF-SIB PROGENY TESTING

The function of our half-sib progeny testing was as a tool to confirm beliefs concerning the extent of genetic variation present in our selected population, and to gain knowledge about individual family performance. Since full-sib work on black walnut is not feasible in the wild population, it is a good approach while waiting for clone bank flowering.

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METHODS

The two half-sib tests reported in this paper were initiated, in 1969 and 1970. For both tests an attempt was made to collect open-pollinated seed from each parental selection that had seed available that year. In most cases, therefore, families were not replicated over years, however, both tests contained sources from southern Michigan to southern Indiana.

The seeds were sown in the Purdue-Shidler nursery, near Lafayette, Indiana, during the fall. The design was a randomized complete block with 3 blocks. After the first year in the nursery, the seedlings were outplanted to several different locations; remaining in the RCBD and arranged in 10-tree row plots.

The oldest study is four years old and because of its youth, total height, total diameter, and germination percent were the only traits evaluated.

RESULTS AND DISCUSSION

Mean family performance versus the commercial check ^{1/}

For the traits evaluated, we were interested in the ability of our selected families to perform in relation to the commercial stock available. Table 2 illustrates that in almost every test the performance of the selected families was superior to the commercial check. At high selection intensities the differences were great. The reason for these great differences is probably due to the high-grading of Indiana walnut, and that when exceptional individuals are located, their performance is much superior to the seed presently being used by Indiana nurseries.

Germination among families is quite variable, and since the commercial stock available today averages 50 percent, an increase in this trait alone would be a boon to walnut culture.

Given a 20 percent selection intensity, our selected families out-performed the commercial check showing a 29 percent and 51 percent increase for the 1969 and 1970 tests respectively (Table 1). Also, the mean for all selected families for the 1970 test had a germination percent higher than the commercial check.

Table 1. -- Germination percent

Test	Percent increase of best 20%	h^2	Reliability ratio
1969	29	.94	.39
1970	51	.84	.39

^{1/} The commercial check is a random sample of the seed used for planting by the Indiana Division of Forestry nurseries.

Table 2. -- Performance of selected families in relation to the commercial check

Test	No. of families	Age	100%		Intensity of selection			
			Ht.	Dia.	38%		20%	
					Ht.	Dia.	Ht.	Dia.
Nursery:								
1969	13	1	6.3	8.1	33.3	17.8	38.0	20.2
Outplantings:								
Pike 1969	4	2	12.0	13.0	37.0	24.0	42.9	28.0
Stem 1969 ^{a/}	7	4	17.9	21.0	44.0	51.0	47.2	53.8
Orange 1969	12	4	10.9	5.1	20.4	16.3	25.4	21.6
Nursery:								
1970	18	1	3.6	1.8	18.9	14.8	26.3	18.1
Outplantings:								
Parke 1970	9	3	12.0	--	20.0	--	20.0	--
Flick 1970	8	3	0.0	0.0	10.6	3.0	13.5	4.9
Orange 1970	18	3	5.9	4.0	19.0	15.0	23.1	19.3

^{a/} Only 1 block remains

Half-sib analysis and heritabilities

All analyses of variance for the height and diameter parameters were statistically significant. Except for the 1969 nursery data for both height and diameter and the Orange, 1970 diameter; all were significant at the .01 level. Germination percent for both tests also proved significant at the .01 level.

Components of variance and heritabilities based on individuals, for all tests were estimated from the following mean square components:

<u>Source of variation</u>	<u>EMS</u>
Families	$\sigma_1^2 = \sigma_w^2 + n\sigma_{RF}^2 + bn\sigma_F^2$
Blocks	$\sigma_2^2 = \sigma_w^2 + 1 - \frac{a}{A} n\sigma_{RF}^2 + an\sigma_R^2$
F x B	$\sigma_3^2 = \sigma_w^2 + n\sigma_{RF}^2$
Within	$\sigma_4^2 = \sigma_w^2$

$$\text{where heritability, } h^2 = \frac{4\sigma_F^2}{\sigma_w^2 + \sigma_{RF}^2 + \sigma_F^2}$$

$$\text{standard error of } \sigma_F^2 = s[\sigma_F^2] = \sqrt{\frac{2}{C^2} \left(\frac{M.S._1^2}{D.F._1 + 2} + \frac{M.S._3^2}{D.F._3 + 2} \right)}$$

(Anderson and Bancroft, 1952)

Where C = coefficient of the σ_F^2 component

Of interest in Table 3 are the heritability estimates and reliability ratios for the nursery and outplanting tests. The tests in Table 2 that were not included in Table 3 were left out because of circumstances making them unsuitable for statistical analysis.

In general, the narrow-sense heritabilities for total height and diameter show that selection for these traits is indeed useful and that beneficial gains can be expected. These heritabilities are comparable with those reported by Bey (1970), and Bey *et. al.* (1971). The reliability ratios are not as good as we would prefer, but in our opinion, they are reasonable. In future work, though, if the RCBD is used, greater precision will be realized by increasing block number. The data for germination percent also demonstrate that good gains can be expected in the future. Narrow-sense heritabilities for this trait were .94 and .84 for the 1969 and 1970 tests respectively. The reliability ratios for both heritability estimates were a respectable .39 (Table 1).

Table 3. -- Components of variance and heritabilities for height and diameter
from two half-sib tests $\frac{a}{b}$

Test	Age	Components			$s[\sigma_F]^2$	h^2	Reliability ratio $\frac{b}{a}$
		σ_w^2	σ_{RF}^2	σ_F^2			
<u>Height</u>							
Nursery:							
1969	1	.1259	.1490	.0893	.0561	.98	.63
1970	1	.1288	.0304	.0244	.0064	.55	.45
Outplantings:							
Orange 1969	4	1.1070	.0226	.1022	.0585	.33	.57
Orange 1970	3	.6612	.0114	.0629	.0300	.34	.47
<u>Diameter</u>							
Nursery:							
1969	1	.0039	.0018	.0010	.0007	.63	.66
1970	1	.0066	.0011	.0014	.0127	.61	.52
Outplantings:							
Orange 1969	4	.0880	.0045	.0127	.0067	.48	.52
Orange 1970	3	.0498	.0010	.0033	.0019	.25	.57

a/ In 1970, the 1969 test was coppiced due to extensive 17-year locust damage.

b/ The ratio S.E. $(\frac{\sigma_F^2}{2})$ was used to give a general indication of the reliability

of heritability. If this ratio is greater than 0.50, reliability is low (Snyder, 1969).

Genotypic and phenotypic correlations

We decided to calculate genotypic and phenotypic correlations on the total height and diameter parameters to validate the relationship expected. The 1970 test was used as an example because the precision is the better of the two tests.

Table 4 illustrates, except for 1970 and 1971 height with 1970 diameter, that both genotypic and phenotypic correlations are very high. We offer no explanation for the two low correlations mentioned. Individually, the height and diameter correlations increased with age as expected since measurements of total height or diameter are the summation of annual effects. All correlations calculated increased with age. The important point to remember is that due to the high genetic correlations between height and diameter, selection for one characteristic would produce meaningful gains in the other.

Table 4. -- Genotypic and phenotypic correlations between height and diameter for the 1970 test

Characters	Genotypic correlations	Phenotypic correlations
1972 height with:		
1970 height	.84	.63
1971 height	.92	.73
1972 diameter with:		
1970 diameter	1.32	.82
1972 height with:		
1970 diameter	.90	.63
1972 diameter	.92	.85
1971 height with:		
1970 diameter	.21	.34
1972 diameter	.63	.44
1970 height with:		
1971 height	.97	.92
1970 height with:		
1970 diameter	.21	.34
1972 diameter	.67	.41

CLONAL TESTS

Measurements obtained from grafted black walnut at the Purdue-Shidler clone bank not only give some indication of our ability to select outstanding trees, but may be utilized directly if vegetative propagation on a large scale becomes a reality. Due to the high value of black walnut, the best clones could be offered for planting either as grafts or rooted cuttings, thus by-passing sexual reproduction and progeny testing by seedlings.

METHODS

The oldest grafts available for statistical analysis are four growing seasons old. Since the site is reasonably uniform, and due to differential grafting success, a completely randomized design was used for all traits and years. Only clones having at least three surviving, undamaged ramets were analyzed.

Analysis of variance provided the clone and error variance components as estimated from the mean squares for all variables following the approach of Mohn and Randall (1971). Broad-sense heritabilities were calculated using the formula $h^2 = \sigma_c^2 / \sigma_c^2 + \sigma_e^2$. Reliability ratios were calculated using the same formula as for the half-sib progeny tests (Table 3).

RESULTS AND DISCUSSION

Table 5 summarizes information for characteristics measured in the clonal tests.

Foliation and defoliation dates

The highest heritabilities and best reliability ratios were obtained for foliation and defoliation dates. Foliation date is of great importance in black walnut due to its susceptibility to late frosts. Frost often causes destruction of central stem tendency, thus a late foliator may escape damaging frost. Generally late foliators are early defoliators and have a short growing season. In spite of this short growing season, there was no indication of reduced growth. In fact, several of the late foliators and early defoliators were among the fastest growers. The correlation coefficient (r) between foliation date and height growth in 1971 was -0.02. Order of foliation was consistent from year to year with latest foliators invariably being late in subsequent years. This relationship was demonstrated by the high correlation coefficient (r = .80) between 1970 and 1971 foliation dates.

Height and diameter

Total height at age two had high heritability and good reliability. Potential for selection and breeding for height growth is indicated by these early estimates. Unfortunately, estimates from older material is lacking since wind damage, top pruning, and thinning removed many ramets and clones from possible analysis of growth parameters.

Table 5. -- Age, means, range of clone means, variance components, broad-sense heritabilities, and reliability ratios from a clonal test

Character	Year grafted	Age	No. clones	No. grafts	Test mean	Range of clone means	Clone variance	Error variance	h^2	a/\bar{h}	Reliability ratio
Foliation date (days) <u>b/</u> **	1969	1	28	146	4.9	0.3 - 15.7	9.380	1.763	.84		.27
Foliation date (days) **	1969	2	27	143	17.6	1.7 - 25.7	22.140	3.707	.86		.28
Foliation date (days) **	69, 70, 71	3, 2, 1	50	224	15.1	2.5 - 25.0	24.866	2.310	.92		.20
Defoliation date (days) <u>c/</u> **	69, 70	3, 2	29	141	13.2	3.3 - 17.8	13.695	4.938	.73		.28
Total height (ft.) **	1969	2	27	141	8.2	6.4 - 10.9	1.026	0.839	.55		.31
Total diam. (DBH in.)*	1969	4	17	68	2.4	1.9 - 3.2	0.062	0.184	.25		.60
Sweep <u>d/</u> **	1969	4	18	80	1.13	0.18 - 3.38	0.268	0.630	.30		.51
Crook (no.) **	1969	4	17	76	1.12	0.33 - 2.0	0.172	0.548	.24		.59
Branch angle (deg.)**	1969	2	27	138	56.2	44.8 - 66.0	13.838	55.982	.20		.49
Branch no. **	1969	1	28	147	7.9	3.7 - 23.3	12.025	17.571	.41		.34
Anthraxnose resis. <u>e/</u> **	69, 70, 71	4, 3, 2	34	146	2.77	1.25 - 4.50	0.430	0.366	.54		.29
$a/ \sigma_c^2 / \sigma_c^2 + \sigma_e^2$											

b/ Days from first graft to show visible leaf

c/ Days from first graft to completely defoliate

d/ Deviation in feet from central stem per foot of total height x 10

e/ Rated 1 (outstanding resistance) through 5 (very poor resistance)

** Significant differences among clones at the 1% level

* Significant differences among clones at the 5% level

Heritability of diameter after the fourth year was relatively low. Nevertheless, they compared favorably with the narrow-sense heritabilities already discussed, and the findings of Mohn and Randall (1971) in cottonwood. Reliability of heritability for diameter was not outstanding, and probably reflected the same problems associated with height measurement in the older material. In addition, growth parameters are better analyzed by statistical designs other than the completely randomized design we were forced to utilize in this study. Growth of some clones has been excellent. In their fourth growing season, grafts grew as much as 6.7 feet in height and 1.3 inches in diameter at DBH. The largest four year old grafts measured 21.1 feet and 3.6 inches DBH.

Sweep and crook

Sweep and crook were not as highly heritable or reliable as was anticipated, however, method of measurement may have affected these variables. Number of crooks was counted subjectively by two independent observers and averaged for each tree. Sweep was measured objectively by the distance the terminal shoot deviated from the base of the tree divided by the height. However, differential effects of staking and pruning undoubtedly had an effect on heritability of both sweep and crook. Heritabilities for sweep (.30) and crook (.24) are high enough to produce meaningful gains in a breeding program. They compare favorably with heritabilities for form traits found in loblolly pine of the same age (Shelbourne and Stonecypher, 1971).

Branch angle and number

Branch angle apparently is not highly heritable in black walnut, even though there were significant differences among clones. A practical method of accurately measuring branch angle on the original selection could not be found, and it was hoped that branch angle could be measured on the grafts. However, branch angle apparently is affected more by leaf weight on the branch than any inherent branch angle as such. Branch angle can vary considerably from day to day and season to season on young trees.

Branch number, on the other hand, shows a relatively high heritability and is quite reliable. Number of branches is a good estimate of "bushiness" in black walnut since clones with many branches were those having a tendency to fork. One clone, not included in the study, never produces a branch during the first growing season after grafting, and branches produced the second year are slender and short, producing an ideal, compact crown.

Anthrachnose resistance

Black walnut anthrachnose (*Gnomonia leptostyla* (Fr.) Ces. and deN.) is a fungus disease affecting the leaves and fruit husk of the black walnut. It causes early defoliation, and therefore, presumably, decreases growth (Berry, 1964). In the 1972 growing season, optimum weather conditions for the spread of anthrachnose, including high rainfall and humidity, and low temperatures occurred. On August 24, 1972, each graft regardless of age was rated subjectively on a scale from one to five with: 1 = few or no leaf lesions, no leaf fall; 2 = leaf lesions evident but only a few leaves fallen and no rachis fall; 3 = average -

leaf lesions and bronzing, some leaf and rachis fall; 4 = more leaf and rachis fall than in 3; 5 = serious defoliation and rachis fall, trees often nearly defoliated. Heritability was high and reliability good for anthracnose resistance, indicating that breeding for improved resistance to this serious disease is possible.

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DEVELOPMENT AND USE OF
JUVENILE - MATURE CORRELATIONS IN A
BLACK WALNUT TREE IMPROVEMENT PROGRAM

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Abstract. -- Cross section discs were cut at predetermined intervals from 19 black walnut trees. Growth rings on each disc were measured. Diameter, height and volume at various ages were determined by stem analysis. Character used for early selection should have the high juvenile - mature correlations. The earliest age for selection should maximize the product of the juvenile mature correlation and the selection differential at that age.

INTRODUCTION

Agricultural geneticists can evaluate progeny performance and make their selection decision at the end of an organism's life cycle or at its maturity, because the materials they work with have a relatively short life span. On the other hand, the forest geneticist faces a dilemma; either he makes an early selection with unknown certainty, or makes a late selection further compounding the interest rate on his initial investment. However, if a juvenile - mature correlation is found, reliable selection in a test plantation can be made at an early age.

Most of the juvenile - mature correlations in forest trees were derived from observations throughout the testing period (Callahan and Duffield 1962, Steinhoff 1970, Squillace and Gansel 1972, La farge 1972). In this study, instead of waiting 30 years for black walnut trees to reach maturity, stem analysis was used to study the past growth history of the trees. Data retrieved from the stem analysis then were used to compute the juvenile - mature correlation.

METHOD

Nineteen black walnut trees in a native mixed hardwood forest in southern Illinois were sampled. Trees were cut at 6 inches and cross section discs of 1-inch thickness were cut at intervals of 1, 2, 3, 4, 5, and 6 feet above the stump and every two feet thereafter. The top surface of each disc was sanded to facilitate viewing.

Diameter of each annual ring (the sum of the longest and the shortest radius) was measured to 1/20 of an inch. Smalian's formula was used to compute the cubic-foot volume at each age.

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RESULTS AND DISCUSSION

Age-Age Correlations

The age-age correlations calculated from individual tree volumes at various ages are presented in Figure 1. The closer the two ages, the higher is the correlation. As a rule of thumb, when the juvenile age is half of the mature age, the correlation for volume is about .9, and when the juvenile age is near one-third of the mature age, the correlation is about .7.

The age-age correlations calculated from diameter inside bark at 4.5 feet above ground, and calculated from total height were not significantly different from those calculated from volume, probably due to the limited sample size.

Which type of early measurement should be used for mature - volume selection?

The early trait used in indirect selection for mature volume should have a high correlation and should be measured easily and precisely. Accurate height and diameter measurements are easier to obtain than volume measurement and are therefore to be preferred. From age 1 through 3, total height of the seedling should be used for selecting volume, because their correlation coefficients are highest among other early traits (Table 1). From age 4 through 11, diameter inside bark at 3.5 feet above ground could be used. However, others may want to use diameter inside bark at 4.5 feet or simply dbh because of the ease of measurement. From age 12 and throughout the later years volume has the highest correlation coefficients, therefore volume should be given priority over height or diameter measurements.

Table 1. -- Correlation coefficients between various early measurements and
cubic foot volume at age 30

Juvenile Years	Vol.	Ht.	Diameter inside bark at			
			1.5'	2.5'	3.5'	4.5'
----- Correlation Coef. -----						
1	.03	.47	.15	.03	.22	-
2	.26	.60	.40	.36	.39	.32
3	.30	.67	.49	.52	.46	.33
4	.39	.61	.56	.63	.65	.52
5	.46	.66	.63	.67	.70	.64
6	.48	.62	.67	.71	.72	.68
7	.52	.66	.66	.71	.72	.69
8	.57	.64	.67	.71	.72	.70
9	.62	.63	.68	.71	.71	.70
10	.66	.66	.67	.71	.71	.70
11	.70	.67	.67	.71	.71	.70
12	.74	.68	.67	.71	.72	.72
13	.79	.68	.68	.72	.72	.73
14	.82	.68	.67	.72	.72	.73
15	.85	.68	.68	.72	.72	.74

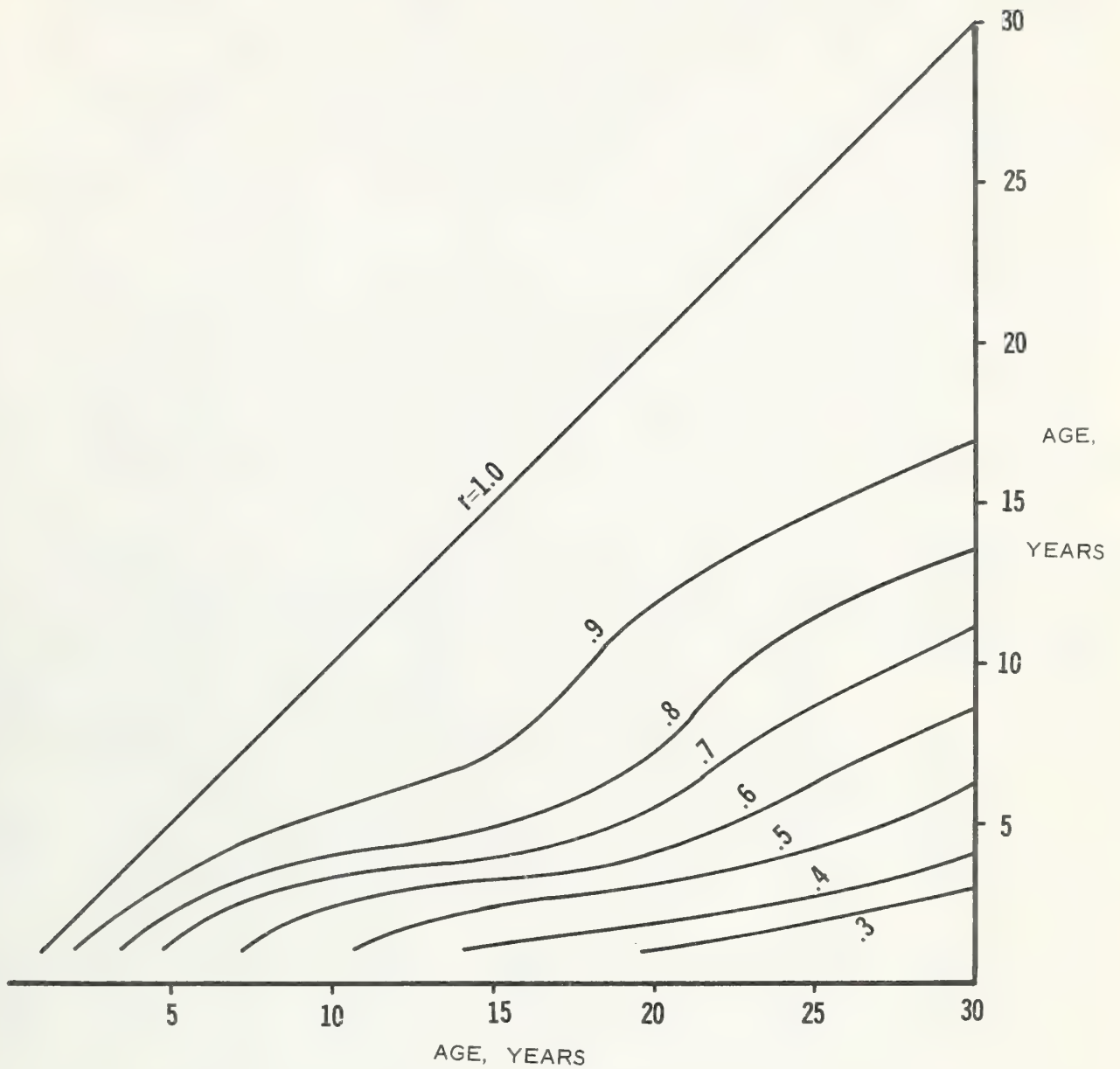


Fig. 1. INDIVIDUAL AGE-AGE CORRELATIONS ON CUBIC FEET VOLUME.

How high a juvenile - mature correlation is high enough for early mass selection?

The correlation between height at early ages and volume at age 30 reaches a plateau at age 3 (Table 1). Therefore, if one chooses height of the saplings as his only criterion for volume selection, he would not obtain any gain by waiting. On the other hand, if the correlation increased throughout the early ages as in the case of volume correlation, how high is high enough?

In an established test plantation, the spacing between trees was fixed. Once the final number of seed trees is determined, the selection differential will be the same at various ages. Therefore, the highest correlation will give the maximum selection gain. On the other hand, if the test plantation is yet to be established, the designer still has the freedom to choose the spacing. Then both correlation and selection differential at various ages must be considered simultaneously. The philosophy here is that if we want to select trees at age X, we should plant the trees at the optimal spacing for trees at age X. Let us assume that the spacing and number of trees per acre in Table 2 are optimal values for black walnut trees, and further that 50 seed trees or selections per acre are desired. One can calculate the percentage of trees saved (column 5 = column 4/column 3), and then find out the selection differential between the selected group and the original population in units of standard deviation. Values in column 6 were taken from table of accurate values for selection intensities by Namkoong and Snyder (1969). It can be easily seen that selection differentials are higher for the earlier ages.

Table 2. -- Gain of volume selection at early ages over age 20

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Age	Spacing	Total trees per acre	Trees to be selected	% of trees to be selected	Selection differential	J-M corr. coef.	Exp'd diff.	Gain
yr.	sq. ft.	Number	Number	%	st. dev.		st. dev.	st. dev.
1	2x2	10890	50	.46	2.92	.29	.85	-.01
2	3x3	4840	50	1.03	2.65	.41	1.09	.23
3	4x4	2722	50	1.84	2.45	.49	1.20	.34
4	5x5	1742	50	2.87	2.28	.61	1.39	.53
5	6x6	1210	50	4.13	2.14	.69	1.48	.62
6	7x7	889	50	5.62	2.01	.74	1.49	.63
7	8x8	681	50	7.34	1.90	.78	1.48	.62
8	9x9	538	50	9.29	1.79	.81	1.44	.58
9	10x10	436	50	11.47	1.69	.84	1.42	.56
10	11x11	360	50	13.88	1.59	.86	1.37	.51
20	20x20	109	50	45.87	.86	1.00	.86	.00

The expected selection differential at the mature age can be estimated by the product of the selection differential at the early age and the juvenile mature correlation coefficient. For example, the expected selection differentials for age 20 (column 8) are obtained by multiplying the selection differentials

(column 6) by the correlations (column 7). The gains of early selection over late selection (column 9) are obtained by subtracting the expected selection differential at age 20 ($= .86$) from the expected selection differentials at various juvenile ages (column 8). The result shows that early volume selections are favored, except in age 1 when the juvenile - mature correlation is low.

For mass selection of black walnut tree by early volume, 6 years seems to be a desirable testing period. However, if column 7 of table 2 is substituted by values in table 1, one can compute the gain of various indirect selections (by juvenile trait) over direct selection (by volume at age 30). It was found that total height at age 3 offered the highest gain among all age - trait combinations. Here again, the product of the juvenile - mature correlation and the selection differential at the juvenile age determines the best criterion and the best age for selection.

It may be desirable to leave more than 50 trees per acre at age 3 because of possible subsequent mortality. A multiple stage selection then can be applied. If one has predetermined to thin a seed orchard at ages 3, 8, and 15, he should plant the trees at 4' x 4' spacing in the beginning. At age 3, the plantation should be thinned to 538 tallest tree per acre. At age 8, the plantation should be thinned to 170 trees per acre, using d.i.b. at 3.5 ft. for selection standard. At the final stage, when the trees are 15 years old, they are selected by volume.

Of course during the multiple-stage-selection one can manipulate the ages for selection as well as the traits for selections to maximize the total selection gain. The total selection gain is defined as the sum of products of the selection differential from one stage to the next and the correlation coefficient from one stage to the next stage.

Practicality of the proposed procedure

Because the correlations were derived from single trees, the proposed procedure could be used with phenotypic selection of individuals in a seed orchard. Since the trees in this study were sampled from a wild stand, the juvenile - mature correlation estimate may be conservative when it is applied to a test plantation.

The use of stem analysis to retrieve past growth history and to construct age-age correlation may be worthwhile for planning a provenance test-seed orchard. For example, 20 trees each from 20 provenances are cut and measured. Data from 400 trees can be used to compute individual juvenile-mature correlations. Selection in the seed orchard is based on individual tree performance. On the other hand data from 20 trees within provenance can be used to compute individual within provenance juvenile-mature correlation. This information may be useful for selecting individual sapling within the provenance. Finally, the provenance means are computed from 20 trees. Those 20 provenance means are used to calculate provenance juvenile-mature correlation. Then in the plantation, the mean values of juvenile performance of each provenance are considered for provenance selection.

Mature trees with known family origin are seldom available. Therefore, the stem analysis may not be practical in finding age-age correlation of family means. In this case, one can not help it but wait for the data to come in.

After he has collected the mean values of the family performance in juvenile stage as well as at the end of the rotation, then he can compute the family juvenile - mature correlation.

The family juvenile - mature correlation obtained through record keeping during the first generation test period would be a valuable asset in planning a family selection in the second generation short term progeny testing or progeny testing-seed orchard scheme. For a short term progeny test in which the test plantation is disposed of at the end of the testing period, the juvenile - mature correlation should be at the peak or high enough for the return of the investment. For the progeny testing-seed orchard, the correlation and the selection differential at each age should be considered jointly.

The simultaneous consideration of the juvenile - mature correlation and the selection differential offers maximum selection gain as well as the maximum genetic gain per unit of area, for the mature trait. If one is interested in maximum gain per unit of area per dollar spent on planting and thinning, he can divide the gain at each age by the cost, then find the criteria that would maximize the quotient. Usually the selection age would be delayed for a few years so that fewer trees need to be planted and thinned. Further, if one is interested in maximum genetic gain per unit of area per dollar per year, he should divide the above quotients by the juvenile age and find out the maximum return.

In the practical tree breeding program, one must consider the flowering age as well as the selection age. The breeding should be done at the later one. In black walnut, trees may be selected at age 3 by total height; but breeding can be done only when trees have reached sexual maturity (age 13). On the other hand, some pines may have flower at age one (Mergen and Cutting, 1957) but the actual breeding work should be carried out at the age with the maximum gain.

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THE USE OF ANTIGENIC PROTEIN POLYMORPHISM AS A TOOL
FOR EVALUATING SELECTED BLACK LOCUST
(*ROBINIA PSEUDO-ACACIA*) CLONES

Roy B. Clarkson, F.H. Huang, and Franklin C. Cech ^{1/}

Abstract.--Antigenic proteins of several clones representing the so-called dominant-stem form of black locust (*Robinia pseudo-acacia* var. *rectissima* (L.) Raber) were compared to clones representing the typical form (*R. pseudo-acacia* L.).

The probability analysis of proteins from dominant-stem forms vs. typical forms showed that there were no significant differences in double diffusion precipitin bands attributable to bole form. Analysis of immunoelectrophoretic results likewise indicated that there were no significant differences in antigenic proteins among the trees studied. It is proposed that, based on antigenic root proteins the dominant stem form is an ecological variant.

Additional analyses were performed on clonal selections grown on strip mine spoils on two diverse sites. The samples collected at Clarksburg, W.Va. consistently generated more precipitin bands than those from Maidsville, W.Va. indicating that environmental differences are expressed in antigenic proteins.

It is suggested that the additional precipitin bands are a reflection of an epidemic attack of locust borer on one of the strip mine locations.

Additional Key Words: Double diffusion, immunoelectrophoresis, environmental effects.

Recent developments in the field of antigen protein analysis have indicated that it is a useful tool for taxonomic, pathological, genetic and physiological investigations (Clarkson and Fairbrothers, 1970; Vaughn, et al., 1967; Vaughn, et al., 1969; Ziegenfuss and Clarkson, 1971; Pickering, et al., 1965; Hillebrand, et al., 1970; Esposito, et al., 1965; 1966; Bozzini, et al., 1970; Lester, et al., 1965; Cristofolini, et al., 1970; Saito, 1968; Klotz, et al., 1963; Cristofolini, 1971;).

The basic purpose of this study was to determine the suitability of serological techniques for detecting antigenic protein differences due to form of black locust, first, in connection with subspecific separation of *Robinia pseudo-acacia* L. and *R. p.* var *rectissima* (L.) Raber, and second in connection with possible antigenic protein variation between well formed and poorly formed trees found on the same site.

METHODS

Roots were collected from one ramet of each of eight clones from a

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strip mine planting near Maidsville, W.Va. Each of these clones was originally selected by the Soil Conservation Service because of its well-formed dominant stem. Four of these clones were originally selected in the vicinity of Harman, W.Va., the area recognized for outstanding dominant-stem individuals, while the other four clones were selected near Byrantsburg, Indiana, an area of essentially diffuse branched individuals. Roots were also collected from all but two of the same clones planted on a strip mine near Clarksburg, W.Va. To determine within-clone variation, collections were made from more than one ramet of several clones on the Clarksburg strip. Collections were also made from a clonal planting in the Clements Nursery near Point Pleasant, W.Va. These clones (originally selected by West Virginia University Personnel), were paired superior and inferior phenotypes from the same location.

Methods of Collecting Roots

Roots were dug and frozen immediately in dry ice and methonal. They were then placed in polyethylene bags and transported in an ice chest with dry-ice. Within a few hours after collection, they were transferred to a freezer where they were stored at -20° C until ready for use.

Sample Preparation

Roots were removed from the freezer, and scrubbed with tap water in a cold room at 4° C to remove any attached soil. This was followed by several washings with tap water. Finally, they were rinsed in cold distilled water.

Clean roots were chopped into the smallest possible pieces (approximately 2 - 4 mm.) A Prolabo crusher pre-cooled with dry-ice, was then used to pulverize the roots. The pulverized roots were then stored in glass jars at -20° C until used.

Protein extractions were accomplished by soaking 5 g of root meal in 10 ml of 2.5 percent saline solution at 4° C for 18 hr. with constant agitation using a magnetic stirrer. After one hour of extraction, the pH value of the extracting solution was adjusted to the original pH of 7.0 using 1N NaOH.

Following the 18 hr extraction period, the mixture was filtered through a millipore filter (diameter 1.2 μ) and centrifuged for 20 min at 9500 x G at 0° C.

The precipitate was discarded and the supernant analyzed for its protein concentration according to the method devised by Lowry, et al.,(1951). Without further purification, the extract was used for immunization.

Immunization of Rabbits

New Zealand white rabbits were used for immunization. Normal rabbit sera, i.e. serum obtained before injections were made, were tested against each antigen to determine whether any non-specific precipitating systems were present.

For subcutaneous injections, one ml. of protein extract was added to one

ml Freund's incomplete adjuvant (8.5 ml paraffin oil plus 1.5 ml Arlacel A) and mixed using a Vortex-Geni mixer. This mixture was injected in the neck region of the rabbit. For intravenous injections one ml of protein extract was injected in the marginal vein of the rabbit's ear.

Two injection series were made, each consisting of subcutaneous injections on four successive days, and intravenous injections on the last two of the four days. A rest period of ten days was allowed between the first and second series of injections.

Five days after the completion of the second series of injections, 20 ml of blood were drawn from each rabbit. The blood was put into a refrigerator at 4° C overnight. The following day, the blood samples were centrifuged (5,000 x G for 20 minutes at 0° C) and the serum was decanted into plastic vials and stored at -20° C.

Double Diffusion

Five ml of one percent Ionagar in a 2.5 percent saline buffer solution at pH 7.0 were poured into a plastic petri dish (55 mm diameter) and allowed to solidify at room temperature. Using a Grabar auto-gel agar cutter, six perimeter wells (6 mm diameter) and one center well (10 mm diameter) were cut simultaneously. The distance between any one perimeter well to the center well (edge to edge) was 6mm. Two-tenths ml of the antiserum was placed in the center well and 0.1 ml of the corresponding antigen was placed in alternate peripheral wells. Finally, one ml of each of three foreign antigens was placed in each of the three remaining wells.

The petri dishes were then incubated for a period of three days at 4° C, and the double diffusion patterns read at the end of this period. The precipitin bands were diagrammed and the patterns photographed for future references. Numbers of bands of identity, partial identity, and non-identity were recorded and analyzed.

Immunoelectrophoresis

Immunoelectrophoresis was performed using a Gelman electrophoresis apparatus according to the Grabar method (1959), modified as follows: The 0.7 percent Ionagar solution was made by adding 0.7g of Ionagar to 100 ml of veronal-citrate buffer at pH 8.2 (51.95g sodium barbital; 2.0g citric acid; 2.25g oxalic acid; 14.7g sodium chloride and distilled water were mixed to make five liters of solution). Twenty ml of this solution were poured into a frame containing six 3 in x 1 in microscope slides. The frame was placed in a humidity tank which was then put into a cold room at 4° C for two hrs while the gel solidified. When the gel had solidified, the frame with the slides was removed from the cold room. A Gelman gel punch was used to make a 2 x 65 mm trough down the center of the slide and two 3 mm wells a distance of 5 mm from the trough.

A Pasteur pipette joined to a vacuum pump was used to remove the excess agar from the wells. Antigens were placed in the wells and electrophoresis was performed at 45 mA for 3.5 hr. Upon completion of electrophoresis, the agar in the trough was removed and antisera was placed in the troughs. The slides were then stored at 4° C for two days while the precipitin bands developed.

Following the incubation period, the slides were stained in amido black. After staining the slides were dried, precipitin bands were diagrammed and the slides stored at room temperature.

Numbers of precipitin bands were counted and analyzed.

RESULTS AND DISCUSSION

Although there were too few pairs of the well vs. poorly-formed trees in the Clements samples for a valid statistical treatment, a probability analysis of the double diffusion data showed that results were non-significant (Table 1), and from this it is inferred that there are no differences in double diffusion bands due to bole form. A careful examination of the data is sufficient to establish the fact that this method is relatively inefficient. Paired samples have a great deal of variation, the range equalling that from among samples. Additionally the maximum number of bands for all trees was four except for tree 203X where the maximum was five. Apparently there was a very significant effect due to test animals. This also may have obscured tree-to-tree effect.

The same criticism can be made for the Maidsville-Clarksburg samples as made for those from Clements except that there was a sufficient number available for a valid probability analysis (Table 2). The results are non-significant, indicating that there is no difference in double diffusion band number due to site. However, because of the great variation within samples this interpretation should not be accepted as conclusive.

The analyses of the immunoelectrophoresis results are presented in Tables 3 and 4. A probability analysis was used to compare the three pairs of well vs. poorly-formed trees on the Clements Nursery. As with the previous portion of the study, the results have indicated that there is no real difference in immunoelectrophoretic patterns between well and poorly-formed trees.

Table 1.--Total number of double diffusion bands, Clements Nursery samples.

Anti-sera	Antigen					
	220s	220x	203s	203x	pa-s	Pa-x-1
220s	3	4	3	3	4	3
220x	3	4	4	5	4	4
220x	3	3	3	4	3	4
203s	3	1	3	4	2	3
203x	3	2	4	4	3	3
Pa-s	2	2	2	3	2	2
Pa-s	4	4	4	4	3	2
Pa-x-1	2	2	2	4	2	2
Pa-x-1	1	3	3	4	2	3

s=well-formed x=poorly-formed

Using the binomial frequency distribution; number of bands "x" greater than "s" is 12, less than "s" is 4, and equal to "s" is 11. Since Prob. $(x, n, p) = \binom{n}{x} (p)^x \cdot (1-p)^{n-x}$, so Prob. $= 2x\{p(x=12)+p(x=13)+p(x=14)+p(x=16)\} = 2x\{(\frac{16}{12}) + (\frac{16}{13}) + (\frac{16}{14}) + (\frac{16}{16})\} x (\frac{1}{2})^{16} = (1820+560+120+16+1) \cdot (\frac{1}{2})^{16} = \frac{2517}{32768} = .0768127441$ larger than critical value .05, a null hypothesis of no difference was accepted, i.e., there was no difference in the number of double diffusion bands between the well-formed and poorly-formed trees.

Table 2.--Total number of double diffusion bands; Clarksburg vs. Maidsville.

Anti-sera	c	m	c	m	c	m	c	m	c	m	c	m	c	m
	4191	4191	4194	4194	4194	4194	8449	8449	8450	8450	8452	8452	8470	8470
c4191	4	4	5	4	4	2	3	3	4	4	4	4	3	3
m4191	3	2	3	2	3	3	2	2	2	2	2	2	3	3
c4194	4	3	3	3	3	3	3	3	3	3	3	3	3	3
m4194	5	3	3	3	3	3	3	3	5	5	5	5	4	5
c8449	6	5	4	5	5	6	6	6	4	4	4	4	5	5
m8449	5	5	5	4	4	4	5	5	5	5	5	5	5	5
c8450	5	3	4	4	4	3	3	3	3	3	3	3	5	5
m8450	5	5	5	5	5	4	4	4	5	5	5	5	4	4
c8452	4	4	5	4	4	4	4	4	4	4	4	4	4	4
m8452	5	5	5	4	4	4	4	4	4	4	4	4	5	5
c8470	5	6	6	6	6	6	6	6	6	6	6	6	6	6
m8470	4	4	4	4	4	4	3	3	3	3	3	3	4	4
Total	103	91	94	88	91	92	96	96	96	96	95	94	94	94

Probability = $2x\{p(x=5) + p(x=6)\} = 2x\{6(\frac{1}{69}) + 6(\frac{1}{64})\} = .218$. Therefore, probability .218 is not less than .05, so we accept the null hypothesis, no difference between Clarksburg samples and Maidsville samples. This may be due to the fact that double diffusion is not as sensitive as immunoelectrophoresis.

s= Well-formed C=Clarksburg
 x= Poorly-formed M=Maidsville

Table 3.--Total number of bands by immunoelectrophoresis. Clements Nursery samples.

Anti-sera	Antigen					
	220s	220x	203s	203x	Pa-s	Pa-x-1
220s	3	4	3	4	4	4
220x	4	6	5	4	4	3
220x	3	3	3	4	4	3
203s	4	5	1	4	3	5
203x	4	3	3	5	4	3
Pa-s	3	6	3	4	3	3
Pa-s	3	5	2	6	5	5
Pa-x-1	1	1	1	2	1	1
Pa-x-2	3	3	4	3	3	4

s= well-formed x= poorly-formed

Using the binomial frequency distribution: the number of bands "x" is greater than "s" is 14, smaller than "s" is 6, and equal to "s" is 7.

Thus: when $b(x, 20, p)$ $x=6$ or less is .06, $x=14$ or larger is .06.

Since this was a two-tail test the probability of getting 6 or less and 14 or larger than "s" or "x" is .12. Since .12 was not less than $\alpha = .05$; a null hypothesis was accepted. This means that there was no difference in the number of immunoelectrophoresis bands between the well-formed and poorly-formed trees. This result was complementary to the double diffusion, peroxidase, and the total protein studies.

The analysis comparing the clones planted at Clarksburg and Maidsville indicated that there were real differences in the immunoelectrophoresis patterns due to site.

The samples from Clarksburg generated a greater number of bands than those from Maidsville, indicating that there are environmental differences expressed biochemically. If these are due to soil-site differences, it would be difficult to quantify possible associated phenotypic differences at this time.¹ If however, as has been suggested, these differences are a reaction to the locust borer attack at Clarksburg, it would seem possible to document phenotypic evidence. No attempt was made to determine the causes for the environmental differences.

It is apparent from this study that the immunoelectrophoresis technique is more sensitive than Ouchterlony's double diffusion method.

CONCLUSION

From an analysis of black locust root extracts, we could not differentiate between well and poorly-formed trees or between dominant stem and diffuse branching types using the Ouchterlony double diffusion or the immunoelectrophoresis techniques. The between-tree variation within treatment was often greater than that due to tree

¹/ Top kill was universal on the Clarksburg planting as a result of the severe borer attack. Sprouts are too small for analysis.

Table 4.-- Total number of bands by immunoelectrophoresis. Clarksburg vs. Madsville.

Anti-sera	Antigen															
	c	m	c	m	c	m	c	m	c	m	c	m	c	m	c	m
c4191	6	4	7	6	5	5	5	5	6	5	6	5	7	6	8	6
m4191	6	4	5	5	5	5	7	6	4	6	6	5	6	5	5	5
c419	5	5	7	4	7	4	6	6	4	6	6	4	5	4	5	4
m419	5	5	7	4	7	5	5	5	5	6	5	5	5	5	5	5
c419	3	4	7	3	5	4	6	6	6	6	6	5	6	5	6	6
m419	6	6	6	5	6	6	8	6	6	6	7	6	6	6	6	4
c8449	4	4	6	5	8	5	5	5	5	4	5	4	5	5	3	3
m8449	6	5	6	4	6	6	5	5	4	4	5	4	5	5	5	5
c8450	8	5	8	5	9	7	5	5	5	6	6	6	6	6	6	6
m8450	5	4	8	7	8	4	8	7	7	6	6	6	7	6	6	5
c8450	6	5	6	4	6	5	9	9	9	8	5	5	9	9	5	6
m8450	6	4	8	7	7	6	8	9	9	9	6	4	5	5	5	5
c8452	6	4	6	4	7	6	6	6	6	6	8	4	6	6	6	5
m8452	6	4	8	4	6	4	6	7	7	7	7	4	6	6	6	6
c8470	5	5	6	4	7	5	6	6	6	6	6	6	6	6	5	4
m8470	5	5	7	5	5	3	6	6	6	6	5	5	5	6	6	6
c8470	5	5	7	6	6	5	7	7	5	5	5	5	5	5	5	6
m8470	5	5	7	5	6	5	7	7	7	7	5	5	5	5	5	6
Total	116	97	140	102	135	106	137	131	103	122	103	123	106	106	106	106

c = Clarksburg m = Madsville
 Since probability $(x, n, p) = \binom{n}{x} \cdot (p)^x \cdot (1-p)^{n-x} = \binom{6}{1} \cdot \left(\frac{1}{2}\right)^6 \cdot \left(\frac{1}{2}\right)^0 = \frac{1}{64}$. Therefore, the probability ("c" larger than "m") = $2x \binom{n}{x} = .0312$. Since .0312 is less than $\alpha = .05$, reject the null hypothesis, accept Ha, that we have a greater number of bands at Clarksburg than Madsville. This result is also complementary with the general protein pattern study. Although there was a difference in terms of the immunoelectrophoretic bands between the Clarksburg and Madsville plantings of the same clonal material, they still had very similar immunoelectrophoretic patterns. Double diffusion is less sensitive than immunoelectrophoresis. Therefore, in this study we detected a difference between the Clarksburg and Madsville plants, but we did not obtain a difference in the previous study by Ouchterlony's double diffusion method.

form. Although the Ouchterlony double diffusion and the immunoelectrophoresis patterns were consistent from one run to the other, there were differences associated with test animals. Conversely, banding differences due to site were evident from the immunoelectrophoresis results. It is postulated that these differences are due to an epidemic locust borer attack on one site. From this evidence, it is proposed that the so-called dominant stem variety is merely an ecological variety.

While the double diffusion technique was least sensitive in this study, it is a more simple method than the immunoelectrophoresis technique and probably should be tested to determine its value before utilizing the immunoelectrophoresis method. If it is found to be inadequate (i.e. too many overlapping bands, excessive variation within samples, etc.) then the immunoelectrophoresis technique should be used. In spite of the disadvantages inherent to antigenic type tests, the authors feel that they are a useful tool for taxonomic and genetic investigations.

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MODIFIED GROWTH CHAMBER ENHANCES VEGETATIVE PROPAGATION
OF SELECTED SWEETGUM AND YELLOW-POPLAR

Paul P. Kormanik and Claud L. Brown^{1/}

Abstract.--A growth chamber was modified with an intermittent spray mist for vegetative propagation of sweetgum and yellow-poplar with both etiolated and nonetiolated current-year shoots. Most of the etiolated cuttings of both species rotted after several weeks regardless of treatment, and the use of such cuttings is questionable. The rooting of nonetiolated cuttings was better than anticipated: over 90 percent success with yellow-poplar and better than 50 percent with sweetgum. Clonal variation in treatment response was apparent and warrants reevaluation of the possibilities for propagation of difficult-to-root species for inclusion in seed orchards.

Additional keywords: Propagation, growth chamber, *Liquidambar styraciflua* L., *Liriodendron tulipifera* L.

Sweetgum (*Liquidambar styraciflua* L.) and yellow-poplar (*Liriodendron tulipifera* L.) represent opposite extremes in response to propagation of cuttings from selected mature trees. Sweetgum is difficult to root even with physiologically rejuvenated cuttings taken from the main bole, although it can be propagated with segments of lateral roots (Brown and McAlpine, 1964; Farmer, 1966). The use of root cuttings is the only proven method of propagating this species, but the technique is laborious and is dependent upon the presence of preformed buds on the roots for reasonable success.

Succulent stem cuttings of sweetgum have been maintained in outdoor mist beds for periods of 4 months without rooting or undergoing appreciable decline and decay. In rare instances when roots are initiated, they are few in number, very fine in texture and opaque in color, and the cuttings seldom survive transplanting.

Stump sprouts or succulent cuttings from forced epicormic branches of yellow-poplar can be propagated readily, but considerable tree-to-tree variation is often encountered. It is not uncommon for cuttings from one clonal line to strike root 75 percent of the time, while those from another may root only 5 percent of the time. Tree-to-tree variability in vegetative propagation is well-known, and horticulturists have bypassed this problem by concentrating on individual lines that propagate readily (Hartmann and Kester, 1968; Adriance and Brison, 1955). Foresters frequently lack this option, and rooting variability frequently limits the propagation of selected clones needed for seed orchards or for specific experimental studies.

Although tree-to-tree variability in root strike with yellow-poplar causes many difficulties, a more serious problem is the variability in root strike encountered in successive trials with selected clones during the same year or

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between years. Usually, an easily rooted clonal line, i.e., one that has a demonstrated rooting percentage of 75 or over, will root throughout the summer even under adverse conditions, although the rooting percentage may drop to 10 or 20 on some trials. Likewise, under similar conditions a clonal line with an average rooting percentage of 25 to 30 may not strike root at all. This type of variability is repeatedly encountered even with vigorous, thrifty stump sprouts purposely produced for vegetative propagation. When succulent plant material is obtained for the first time from selected mature trees (McAlpine and Kormanik, 1972), the quality may be less than desirable or below optimum, and rooting success may be quite low. In fact, under these conditions, many selected trees are discarded which may be badly needed for seed orchards or specific studies.

Over the past 5 years, many new rooting techniques have been tried at the Forestry Sciences Laboratory, USDA Forest Service, and the School of Forest Resources, University of Georgia, Athens, Georgia, in an attempt to reduce tree-to-tree and trial-to-trial variability in root strike. Until recently, almost all of our propagation work was done in raised outdoor mist beds of conventional design, with little progress in reducing variability. Whenever daily weather conditions are favorable (i.e., 24 to 35°C.), good rooting results are obtained, but when night temperature drops below 18°C. and daily temperatures are lower than normal, treatment differences are erased and rooting variability becomes a serious problem. Under the conditions of propagation being investigated at this location, environmental factors (especially temperature fluctuation) seem to be affecting root strike and to be an important factor in rooting variability.

A large growth chamber became available during the past summer (1972) at the School of Forest Resources, and it was adapted as a propagation mist chamber. By keeping temperature fluctuation at a minimum, we believed much of the rooting variability could be eliminated. Three different pilot studies were run with the chamber before a long-term study was installed. The results of these studies were quite encouraging and are reported here.

GENERAL METHODS

All propagation in the modified growth chamber was conducted under an 18-hour photoperiod with 26°C. day temperatures and 23°C. night temperatures. The outdoor mist schedule of 5 seconds per minute during the light period was started in the chamber. When it proved to be too high, it was adjusted downward until a time schedule of 5 seconds every 3 minutes proved satisfactory. The rooting medium was the standard mixture of 1:1 silcia sand and peat moss used at this location for many years. The medium was steam-sterilized for 24 hours before being placed in the chamber.

SPECIFIC METHODS AND RESULTS

Study No. 1: Comparison of outdoor and chamber mist beds for rooting response of two yellow-poplar clones of proven rootability from etiolated and nonetiolated cuttings.

Twenty-four, 4-year-old stems of clone 2 (good rootability) and the same number of clone 3 (fair to poor rootability) were cut 3 feet high during early March in a clonal outplant plantation. Twelve stems from each clone had metal frames built over them and covered with 50-mil black vinyl plastic to exclude light. The twelve adjacent stumps of each clone were left undisturbed to permit sprouts to develop normally. By mid-July, sprouts had developed sufficiently well to provide adequate numbers of suitable cuttings, and they were harvested and placed in the appropriate mist beds. The cuttings were removed at the end of August.

Because earlier tests with these two specific clones gave the best results with 0.8 percent indolabutyric acid (IBA) in talcum, this concentration was used in the present study. The purpose of this test was to compare the results of the standard treatment with those obtained in a growth chamber with normal and etiolated cuttings.

Discussion of Results

The stumps covered with black plastic produced an abundant supply of etiolated cuttings, which varied from 12 to 36 inches in length. These were, of course, much longer than those cuttings from the uncovered stumps; the latter ranged from 6 to 18 inches in length.

Space limitations in the growth chamber permitted the use of only 4 trays for this study. The trays were about 2 feet square and 6 inches deep. In each tray, we planted either 30 of the etiolated or normal cuttings. In our outdoor beds, we planted three rows of 12 cuttings each, or 36 cuttings per treatment per clone. The excessive rise in temperature under the black plastic in the open field precluded the replication of the study later in the summer. The study was closed on August 22, 1972. The rooting percentages from this study are summarized in table 1.

Table 1.--Rooting percentages for etiolated and normal stump sprouts from two clonal lines of yellow-poplar

Clone number	Outdoor bed		Growth chamber	
	Normal	Etiolated	Normal	Etiolated
	----- Percent -----			
2	72	5	90	3
3	39	0	93	3

Within 10 days after being put into the mist beds, most of the etiolated cuttings underwent rapid senescence and died. Some of the cuttings did strike root, but with their small, nongreen leaves, they were unable to sustain growth and eventually succumbed. All of the surplus etiolated cuttings were placed in the outdoor beds (perhaps a hundred more than used in the experimental study itself), and all of these became necrotic within 2 weeks. Obviously, the use of etiolated cuttings of yellow-poplar under similar propagation procedures should be discouraged.

The rapid root development of the yellow-poplar clones in the controlled growth chamber was extremely encouraging, as shown by the rooting percentage in table 1. After 20 days, the rooted cuttings in the outdoor mist beds had two to four roots about 1 to 1-1/2 inches long, whereas the chamber cuttings possessed three to five times this number of roots, which were growing out the bottom of the trays when the study was closed on August 22 (fig. 1).

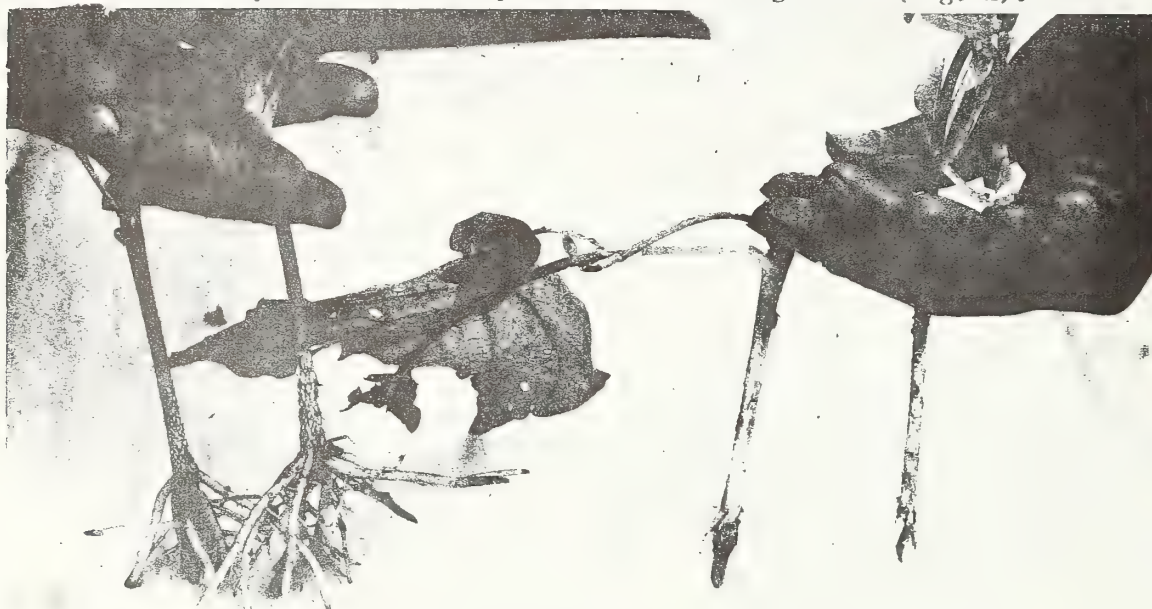


Figure 1.--Root development on yellow-poplar propagules in modified growth chamber (left) was four to five times greater than that on propagules from outdoor mist beds (right) after 20 days.

With clone 2, rooting percentage in outdoor beds often ran as high as 70 to 75 whereas clone 3 in our previous tests seldom ran as high as 40 percent, with 25 to 30 percent being the norm. If the few unrooted cuttings had remained longer in the chamber, it may have been possible to obtain 100 percent root strike for both clonal lines.

Study No. 2: Vegetative propagation of difficult-to-root clones with different combinations of growth hormones

By the end of July, the superiority of rooting yellow-poplar inside the chamber was evident, and a second study with different growth hormones on four of our newly established yellow-poplar clones was initiated. These clones had been initially selected and established in 1970 from older parents, and some difficulty was being encountered in getting them to root in sufficient numbers for our purposes in the outdoor misting beds. The clones used in this study were YP 70-6, YP 70-12, YP 70-14, and YP 70-31; these were placed in the chamber on August 7. The six treatments used and the methods of application were as follows:

1. Treatment 1--Commercial 0.8 percent IBA in talcum--basal dip application
2. Treatment 2--500 p.p.m. IBA paste in lanolin--basal application

3. Treatment 3--500 p.p.m. each of 2-4D and indoleacetic acid (IAA) in lanolin--spread around the stem at the first exposed node above the rooting medium
4. Treatment 4--Same as treatment 2 except that gibberellic acid (GA_3) at 10 p.p.m. and kinetin (K) at 100 p.p.m. in lanolin paste were smeared around the stem at the second internode below terminal bud
5. Treatment 5--Same as treatment 3 except that GA_3 at 10 p.p.m. and kinetin at 100 p.p.m. in lanolin paste were smeared around the stem at the second internode below terminal bud
6. Control --Without hormones.

Discussion of Results

An abundant supply of cuttings for all clones was not available, and all clones could not be represented in each treatment. However, the studies were preliminary and the emphasis here was on the trial itself. The clones that were selected were not necessarily the most difficult ones to propagate; however, they are not classified as easy to root. We were fortunate enough to have these clones under intensive care in outdoor transplant beds.

The two most important observations from this study were: (1) the tremendous variation among clones in response to treatment, and (2) the enhanced rootability of the controls YP 70-12 and 14 under controlled conditions (table 2). These two clones had previously rooted with such difficulty for 2 years in outdoor beds that two cells in the study were left open because of the scarcity of cuttings.

Table 2.--Rooting percentages in four yellow-poplar clones at the end of 21 days in the growth chamber

Number	Control	0.8% IBA	IBA paste	2-4D IAA paste	IBA paste GA_3 + K	IAA + 2-4D paste GA_3 + K
----- Percent -----						
YP 70-6	20	60	0	30	0	60
YP 70-12	80	80	0	0	<u>a/</u>	<u>a/</u>
YP 70-14	40	40	10	10	<u>a/</u>	<u>a/</u>
YP 70-31	10	30	0	60	0	<u>a/</u>

a/ Cuttings available of specific clones were insufficient to be included in experiment.

With a single nonreplicated trial, nothing can be said about the response to specific treatments, but the fact that the controls in all clones rooted to varying degrees is evidence that temperature fluctuation in outdoor beds may be one of the main causes of rooting variability. It also appears that 0.8 percent IBA in talcum still provides a reasonable chemical aid to propagation of this species. The 500 p.p.m. IBA applied in lanolin paste over the entire buried portion of the cutting was apparently toxic and resulted in excessive rotting.

With all clones, the proliferation of lenticels and phloem was greatly stimulated with the IAA-2-4D treatment, and additional studies with different concentrations of these chemicals are planned. Although attempts to find a single best treatment for each clone may not be feasible or warranted at this time (table 2), the development of a method of propagating difficult material is encouraging.

Study No. 3: Comparing rootability of etiolated and nonetiolated epicormic branches from sweetgum in a modified growth chamber.

In February 1972, 12 sweetgum trees averaging 10 to 12 inches d.b.h. were partially girdled to stimulate the development of epicormic branches, as previously reported for other species as a means of obtaining physiologically rejuvenated cuttings (Kormanik and Porterfield, 1966; McAlpine and Kormanik, 1972). Circular styrofoam collars were fitted around seven of the trees, and black plastic polyethylene was placed around the boles to produce etiolated epicormic branches. The other five trees were left uncovered to permit normal epicormic branches to develop.

By July 11, five of the covered trees and two of the uncovered trees had developed enough epicormic branches so that a minimum of 50 cuttings could be collected for use. In order to assess any possible clonal variation in rootability, the cuttings from each tree were kept separate by treatment. We were unable to include a separate control because insufficient cuttings were available from some of the clones. To overcome this deficiency, a total of 48 normal cuttings were randomized and used as controls. A like number of etiolated shoots from clones 72-1, 2, and 3 were randomized and used as controls.

The treatments used were the same as in study 2 with yellow-poplar.

Discussion of Results

This study was the last and most informative one of our trials during 1972. The percentages in table 3 depict the conditions of the cuttings as of September 11. At that time, a noticeable buildup of hydrogen sulfide was detected when the specimens were examined on the biweekly schedule. Except for noting this buildup, no attempt was made at that time to provide more aerobic conditions for the media. Within 10 days, all newly formed roots had died and the cuttings were rapidly deteriorating. The study was abandoned, and the growth chamber was thoroughly cleaned before new studies were initiated.

Table 3.--Rooting percentages for etiolated and nonetiolated epicormic branches from five parent sweetgum trees at end of 60 days

Clonal Number ^{a/}	Treatments				
	0.8% IBA	IBA paste	IAA + 2-4D paste	IAA + 2-4D GA ₃ + K paste	IBA GA ₃ + K paste
	----- Percent -----				
SG 72-2E	50	40	40	10	70
SG 72-3E	15	0	0	0	0
SG 72-4E	30	10	0	0	20
SG 72-5N	20	10	20	20	0
SG 72-6N	60	30	40	30	60

^{a/} E after number identifies etiolated cuttings; N identifies nonetiolated ones.

The problem arose because the previously sterilized trays of media were stored in the chamber for several weeks before use. In the high temperature and humidity regime, aeration was impeded and anaerobic respiration gradually built up over 3 to 4 months. Because of this problem, we eliminated peat moss from the media, and after 6 months we have encountered no difficulty from using a medium-sized sterilized sand.

The variation in root initiation and root growth among the different clonal lines in response to specific treatments was striking, but overall propagation was so successful that these results overshadowed the variability in this trial (table 3). In our opinion, any technique that results in 70 percent root strike within 60 days from 30-year-old sweetgum should be given a second look.

During the summer, a great many surplus cuttings from all five etiolated sources were available, and these were placed in outdoor mist beds. All of the cuttings died in about 3 to 4 weeks except those from the SG 72-2E clone; however, the cuttings from this tree did not root in the outdoor mist beds.

Although the variation to treatment from the nonetiolated cuttings was extremely wide, those that died did not succumb nearly as rapidly as the etiolated ones. The range in response is, however, thought-provoking. In a given treatment of similar and very uniform material, some cuttings rooted, the bases of others turned light in color (a change which usually indicates impending root strike), while other cuttings remained the same as when they were collected 2 months previously.

CONCLUSIONS

The exploratory studies reported here indicate that better approaches are possible for prescribing methods of vegetative propagation of difficult-to-root hardwood species. While initially we may be forced to obtain juvenile material to propagate selected trees, a better understanding of the species response to rooting hormones under specific conditions may alter this requirement. Although the cost of propagating trees in growth chambers for general outplanting would be prohibitive, the same costs may be justified for seed orchards. Furthermore, one may improvise ways to control temperature, light, and humidity, within desirable limits for large-scale propagation without costs becoming prohibitive.

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SWEETGUM POLLEN TESTING

James W. Beland^{1/}

Abstract.--Freshly extracted sweetgum pollen germinated within 4 hours on hanging drops of Nygaard's medium. Ninety to 100 percent of fresh pollen germinated, but after forced-air extraction and refrigerated storage, germination varied from 4 to 71 percent. With the procedure described, pollen can be rapidly and conveniently tested for viability prior to controlled pollinations.

Additional keywords: Germination medium, pollen application, pollen extraction, pollen germination, Liquidambar styraciflua.

Fast, simple, and accurate techniques for testing pollen germination are needed if viability is to be checked before making controlled pollinations. With the technique described, freshly collected sweetgum (Liquidambar styraciflua L.) pollen germinated in 4 hours on a medium that is simple to prepare and needs no autoclaving.

METHODS

Catkin-bearing branches were collected from three trees on the Harrison Experimental Forest near Gulfport, Mississippi, during the last week in March 1970. Anthers were mature at the time of collection. Pollen was collected in three ways: (1) branches inserted into water-filled bottles in the laboratory and pollen collected as anthers dehisced; (2) mature catkins (one layer thick) dried in kraft bags and pollen extracted by shaking and screening through voile cloth; and (3) the forced-air techniques described by Snyder (1961) for pine pollen. Extracted pollen (2 and 3 above) was stored at 4° C in cotton-stoppered vials at 50 percent relative humidity.

Germination was tested in the laboratory at 22° to 24° C using Nygaard's (1969) medium, designated BKPS. This medium was prepared by dissolving 100 mg H₃BO₃, 300 mg Ca(NO₃)₂·4H₂O, 200 mg MgSO₄·7H₂O, 300 mg KH₂PO₄, and 100 g sucrose in 1 liter of distilled water, and adjusting to pH 5.2 with 0.01 N NaOH. Culture chambers similar to those described by Fechner (1958) were prepared by pouring paraffin to a depth of 5 mm in 60 x 20 mm disposable petri dishes. Twelve holes were cut with a No. 3 cork borer as the paraffin solidified. Two drops of medium filled each hole sufficiently to allow the drop to hang with minimum convexity when inverted. When applying pollen the dish cover was removed and a mylar tube, 48 x 200 mm long, inserted to

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enclose the holes. A dehiscing catkin or a camel hair brush filled with pollen was inserted at the top of the tube. A gentle tap sent pollen falling onto the medium in a well-distributed pattern. There were no convection disturbances. The dish was inverted immediately after replacing the cover. Viability was estimated after 4, 18, and 21 hours by counting the number of pollen grains out of 100 with intact pollen tubes whose length was twice the diameter of the grain.

RESULTS AND DISCUSSION

Fresh pollen.--All pollen grains from two of the trees germinated. Germination from the third tree averaged 98 percent and ranged from 90 to 100 percent. Germination was complete in 4 hours. In one test pollen from tree No. 1 was mixed into the medium rather than dusted on the surface. Mixing depressed germination percent (mean 55 percent, range 14 to 100 percent) and increased germination time to 21 hours.

Stored pollen.--Drying pollen in kraft bags in the laboratory depressed germination slightly. After 40 hours of drying and 30 hours of refrigerated storage, germination ranged from 80 to 97 percent. Drying for 64 hours and storage for 6 hours resulted in slightly better germination--89 to 98 percent. Time required for complete germination of stored pollen increased to 18 hours.

Forced-air drying for 96 hours followed by refrigerated storage for 7 hours was devastating. Germination ranged from 4 to 71 percent and time for complete germination increased to 21 hours.

Pollen should be dusted onto the surface rather than mixed into solution with the medium. Surface germination simulates natural conditions under which pollen grains adhere to stigmatic surfaces and receive nutrients, moisture, and aeration. Clumping of grains toward the center is also reduced when pollen is on the surface.

The treatment described here--surface application of pollen onto a nearly complete nutrient medium in a specialized hanging-drop chamber--has not been reported previously. Duffield (1954) and Worsley (1959) tested conifer pollens in hanging drops of distilled water. Nygaard (1969) used BKPS, but not in a hanging drop, to study germination in Pinus mugo. Fechner (1958), testing four Rocky Mountain conifers, mixed pollen in 2 percent sucrose solution in a hanging-drop chamber similar to the one reported in this paper. Tucovic (1972)^{2/} germinated Quercus robur pollen in hanging drops of 15 percent sucrose solution.

^{2/} Tucovic, Aleksandar. Develop breeding techniques for oaks. In PL 480 Final Technical Report (Project E 30-FS-6) (Unpublished), p. 10-18. Institute for Forestry and Wood Industry, Kneza Viseslava 3, Belgrade, Yugoslavia. 1972.

Germination of fresh sweetgum pollen from dehiscing anthers can be quickly, easily, and accurately tested in modified hanging drops of BKPS culture medium. No autoclaving is necessary because the test is completed within 4 hours (before fungi develop). The medium can be stored in a refrigerator at 4° C for 1 week and drops placed into pre-prepared culture dishes as needed. Clumping of grains is minimized because of the short culture time and low convexity of the hanging drop surface. Grains are observed directly through the petri dish at 40X magnification without inverting or uncovering.

The successful use of hanging drop germination techniques and nutrient culture media used by others suggests that the techniques and medium reported in this paper may be effective for testing pollen from other species of hardwoods and conifers.

Extracted and stored pollen has lower germination and requires more time on the medium. Forced-air extraction as accomplished in this study destroys much of the viability.

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STEM VOLUME ESTIMATION IN YOUNG
COTTONWOOD CLONES -- WHICH EQUATION?

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Abstract.--Stem form characteristics were studied in nine cottonwood clones and a nursery run lot. Form quotient differences outside bark among the clones were closely related to clonal bark thickness differences. Ten individual simple linear regression equations for predicting total cubic-foot stem volume outside bark from total height and diameter at breast height were derived. A pooled equation combining all the data was also derived. Statistical tests indicated that the regressions and the intercepts were not equal and thus the data should not be combined.

However, cubic foot volumes were estimated for each of the clones using the pooled equation and an equation previously published. Both of these equations predicted volume accurately enough in this study to allow a true ranking of the clonal lines for stem volume. Conversely, an accurate estimate of actual wood volume production of an individual clone in response to a treatment will most likely require individual clonal equations derived from inside bark data.

Additional keywords: Linear regression, Populus deltoides.

Volume is frequently chosen, rather than height or diameter as a more meaningful way to evaluate tree growth. This is logical if a volume equation of the required precision is available. Volume of a tree is generally estimated from three parameters: total tree height, diameter at 4 1/2 feet either inside or outside bark, and some measure of stem taper. Stem taper differences among trees are frequently ignored when volume equations are developed for young trees (Perry and Roberts, 1964, Schmitt and Bower 1970; Mohn and Krinard 1971). Stem taper differences among cottonwood (Populus deltoides Bartr.) clones conceivably could be large enough to result in volume estimation errors if such a general volume equation is used. In this paper, the stem attributes of nine clones and a nursery run lot were examined to determine (1) if there are differences in stem form between clones and (2) if general volume equations are of sufficient accuracy to rank clones in clonal test plantations and to accurately measure the response of a clone to experimental treatments such as fertilizer or irrigation.

MATERIALS AND METHODS

The data examined were obtained from measurements made on trees removed in thinning a test containing 9 clones and a nursery run lot. At the time of measurement, the sample trees were either 3 or 4 years old from cuttings and were growing in a replicated spacing-irrigation plot on the Texas A&M University farm in Burleson County, Texas. Approximately equal numbers of trees were sampled at years 3 and 4 from each of three spacings; 5' X 10', 6' X 12', and 7' X 14'. Sample trees were chosen on a mechanical basis to enlarge the 5' X 10' spacing to a 10' X 10' spacing, etc. The average number of trees sampled per

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clone was 33. The trees were felled at ground line and diameter measurements were made outside bark at 4.5 feet, 5 feet, and then every 5 feet until less than 5 feet remained in the tip of the tree. The length of the tip was recorded to the nearest tenth of a foot. The volume of each 5 foot section was calculated using Smalian's formula. The tip was treated as a paraboloid to determine its volume.

Form quotient values outside bark were calculated for each stem by dividing the stem diameter at a height midway between 4.5 feet and the top of the tree by the diameter at 4.5 feet. Bark thickness was not taken with the diameter measurements at the three and four year thinnings. In order to get an estimate of bark thickness, fifty standing trees of each of the nine clones and the nursery run lot were sampled at five years. Two bark thickness measurements were taken on opposite sides of the tree at 4 1/2 feet to the nearest twentieth of an inch and then averaged. The form quotient and bark thickness data were subjected to an analysis of variance.

A simple linear regression equation ($Y = a + b X$) was fitted to the data of the nursery run material and each of the nine clones by least squares regression. A simple linear regression through the origin ($Y = b X$) was also fitted to the ten sets of data. Actual total tree measured volume was the dependent variable and $(\text{Dbh})^2$ times total height was the independent variable. All data were then combined to derive one single equation. In order to test for heterogeneity, the regression data were analyzed by a pooled regression procedure (Hemmerle, 1967).

Two approaches were used to determine the relative accuracy of the combined equation and a volume equation previously published by Mohn and Krinard (1971). First, the pooled volume equation and the equation of Mohn and Krinard were used to estimate clonal cubic-foot stem volume outside bark for each sample tree. A mean predicted volume for each clone and each equation was then calculated. The clones were then ranked according to measured volume and predicted volume by the two equations. Secondly, the percent error was calculated for each clonal volume determination. Percent error was determined relative to the mean measured volume for the two equations as follows:

$$100 \times \frac{(\text{Predicted volume} - \text{measured volume})}{\text{measured volume}} .$$

RESULTS AND DISCUSSION

The mean heights and diameters, the range of heights and diameters within clones, and the mean volumes are given in Table 1. The average spread in heights within a clone was 17.3 feet, whereas the average diameter spread was 3.4 inches. Measured volume among clones ranged from .8 to 2.7 cubic feet.

Form quotient differences outside bark among the clones are evident (Table 2). The clone NE-316 has the largest form quotient (.70) while clone S13C3 has the smallest (.59). Bark thickness differences among the clones are also present (Table 2). The clone with the largest form quotient, NE-316, has the thinnest bark. The clone with the thickest bark, S4C2, has next to the smallest form quotient. The linear correlation between form quotient and bark thickness is quite high ($r = .88$) for this particular set of data and statistically significant at the .01 level. The r^2 value indicates that a large majority (77 percent) of the variability in the outside-bark form quotient differences is

Table 1.--Mean height, diameter and volume measurements for the nine clones and the nursery run lot

Clone	feet		inches		cubic feet
	mean height	height range	mean diameter	diameter range	mean measured volume
Alabama 11	32.0	20.0-40.5	3.1	1.7-5.2	.8
NE-316	33.4	25.0-40.0	3.0	1.8-4.1	.8
S4C2	34.0	29.5-41.0	4.0	3.0-6.4	1.3
S7C1	41.6	31.0-52.0	5.2	3.1-7.2	2.7
S7C3	40.6	28.0-48.5	4.9	2.6-6.5	2.3
S7C15	41.4	29.0-50.5	4.7	2.9-6.3	2.2
S7C16	40.3	30.0-48.0	4.3	2.1-5.5	1.8
S7C23	39.9	30.0-47.5	4.9	3.2-6.7	2.3
S13C3	37.2	32.5-42.5	4.5	3.6-6.1	1.6
Nursery run	35.6	27.5-44.0	4.2	2.7-6.4	1.6

Table 2.--Mean form quotient outside bark and bark thickness for the nine clones and the nursery run lot^{A/}

Clone	Form Quotient	Clone	Bark Thickness
NE-316	.70 a	S4C2	.32 a
Alabama 11	.68 ab	S7C3	.27 b
Nursery run	.66 bc	S7C16	.24 c
S7C16	.65 cd	S7C23	.24 c
S7C1	.64 d	S13C3	.24 c
S7C23	.64 d	S7C1	.24 c
S7C15	.63 de	Nursery run	.23 c
S7C3	.62 e	S7C15	.22 c
S4C2	.62 e	Alabama 11	.12 d
S13C3	.59 f	NE-316	.11 d
mean	.64	mean	.22

^{A/} Averages sharing a common letter within columns are not significantly different at the 5 percent probability level by the Duncan test.

associated with bark thickness differences among the clones. However, clones S7C15 and S4C2 have nearly identical form quotients but differ in bark thickness by .1 inches. Clones S7C1 and S13C3 have an identical bark thickness (.24") but differ by .05 in form quotient. Some differences among clones in stem form inside bark are suggested by these data.

The regression equation statistics for the 9 clones and the nursery run lot are given in Table 3. The variability among the regression statistics of the individual clones is sizeable, the Y intercept values ranged from .001 for

clone S13C3 to .211 for clone S7C15. The regression coefficients ranged from .00191 for clone Alabama 11 to .00233 for clone NE-316. It is of interest to note that the tree size, the measured mean volume, the form quotient and bark thickness values of these two clones are very similar. However, the regression of volume on $(\text{Dbh})^2$ times height is very different for the two clones.

Table 3.--Regression equation statistics

Clone	# of sample trees	a	b	$s_{y \cdot x}$	r^2
Alabama 11	35	.143	.00191	.08	.96
NE-316	35	.039	.00233	.08	.95
S4C2	31	.103	.00201	.09	.98
S7C1	28	.048	.00220	.15	.99
S7C3	38	.025	.00222	.16	.97
S7C15	31	.211	.00201	.14	.98
S7C16	32	.192	.00207	.16	.94
S7C23	31	.126	.00214	.14	.98
S13C3	27	.001	.00212	.14	.94
Nursery run	41	.041	.00225	.09	.99
all combined	329	.075	.00216	.13	.98
Mohn & Krinard	650	.211	.00221	.28	.99

The variability among the regression statistics would indicate that the individual regressions should not be combined to arrive at a single equation. The pooled regression analysis confirms this (Hemmerle 1967). The slope of the regression lines and the intercepts of at least some of the clones were not equal. The coefficients of the two clones not native to Texas, Alabama 11 and NE-316, differed most noticeably from the other clones. The data for these clones were removed and the data reanalyzed for heterogeneity with seven clones and the nursery run lot. The statistical tests still indicated that all of the regression coefficients and the intercepts were not equal to each other. The analysis of the regressions through the origin indicated that the intercepts of five of the ten sets of data were equal to zero: these five sets of data all had intercepts beginning with zero (Table 3). Thus, pooling the data to get a combined equation is not strictly valid.

The variability among the clonal equations indicates that general equations derived from nursery run stock using only height and diameter would generally be unsuitable. However, deriving individual equations for each clone or calculating form factors for clones could be quite troublesome and expensive. General equations that were not too far in error would therefore be used. In this study, the pooled volume equation using all the data and the equation of Mohn and Krinard were used to predict clonal cubic-foot stem volume outside bark. The clones were then ranked (Table 4) according to actual measured volume and predicted volume. The clonal ranking remained essentially unchanged from the ranking obtained from measured volume. In some cases, accurate estimates of true volume production may be needed. Table 5 indicates the errors which resulted when the predicted clonal volumes were compared with the measured volumes.

Table 4.--Relative ranking of the nine cottonwood clones and the nursery run lot according to various methods of volume determination

Clone	Ranking		
	Actual measured volume	combined equation	Predicted volume from equation of Mohn & Krinard
S7C1	1	1	1
S7C3	2	2	2
S7C23	2	2	2
S7C15	3	3	3
S7C16	4	4	4
S13C3	5	5	5
Nursery run	5	6	6
S4C2	6	7	7
NE-316	7	8	8
Alabama 11	7	8	8

Table 5.--Percent error^{B/} in the volume determinations by the combined equation and the equation of Mohn & Krinard

Clone	Combined equation	Equation of Mohn & Krinard
-----Percent-----		
S7C1	- .7	+ 6.6
S7C3	- .4	+ 7.4
S7C23	-1.3	+ 7.0
S7C15	+ .5	+ 8.8
S7C16	-2.7	+ 7.1
S13C3	+6.8	+18.0
Nursery run	-1.9	+ 8.9
S4C2	+4.0	+17.6
NE-316	-2.6	+16.9
Alabama 11	+1.3	+20.8

$$\text{B/ Determined as } 100 \times \frac{(\text{Predicted volume} - \text{measured volume})}{\text{measured volume}}$$

The percent error for the combined equation ranged from -2.7 for clone S7C16 to +6.8 for clone S13C3. The percent error for the equation of Mohn and Krinard ranged from +6.6 for clone S7C1 to +20.8 for clone Alabama 11. The clones with the largest percent error for the Mohn and Krinard equation are those clones having low and high form quotient values.

SUMMARY AND CONCLUSIONS

The outside-bark form quotient varied from .59 to .70 in these young cottonwood clones. A close linear correlation ($r = .88$) was found between clonal form quotient and bark thickness. The data obtained here suggest that cottonwood clonal differences in form quotient inside bark in young trees are

probably small. These results parallel those found by Pederick (1970) for families of loblolly pine (*Pinus taeda* L.).

When individual regressions were run on the nine clones and the nursery run lot, there was sizeable variability among the regression coefficients and the Y intercepts. Statistical tests indicated that the slopes of the regression lines of the ten individual equations were not equal. The Y intercept value for five of the ten sets of data was equal to zero. Thus, a combined equation pooling all the data was not statistically valid. However, in this study with these particular clones, cubic foot volumes estimated from the combined equation and an equation published by Mohn and Krinard ranked the clonal lines for stem volume relative to measured volume accurately enough for the purpose of the study. The equal utility of these two equations suggests that in general among clone form differences outside bark may not be sufficiently large to seriously affect ranking clones for total stem volume. Conversely, accurate estimates of clonal volume production were not obtained with the combined equation and the equation of Mohn and Krinard. If an accurate estimate of actual wood volume production of an individual clone in response to some experimental treatment is wanted, then individual clonal equations or equations involving form based on inside bark measurements will be required.

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SESSION V

POTPOURRI

MODERATOR: R. E. SCHOENIKE

COMPARISONS WITHIN AND BETWEEN POPULATIONS OF PLANTED SLASH AND
LOBLOLLY PINE: A SEED SOURCE STUDY

Donald E. Cole^{1/}

Abstract.--Six slash pine seed sources and six loblolly pine seed sources were planted at eight planting locations in the Atlantic Coastal Plain and Piedmont of Florida, Georgia, and South Carolina in 1958-59.

Loblolly pine was significantly more productive than slash pine, producing 61-49% more volume and 54-46% more weight of wood than slash pine. The species did not differ in percent fusiform rust infection, but slash pine was higher than loblolly pine in measures related to severity of infection. Slash pine was higher in unextracted wood specific gravity than loblolly pine. Differences in height were not significant, but loblolly was larger in diameter and had higher survival than slash pine. Differences among seed sources were generally minor in both species.

Additional keywords: Pinus elliottii var. elliottii, P. taeda, productivity, species comparisons, seed source, fusiform rust, specific gravity.

INTRODUCTION

This study was established by Continental Can Company in 1958. The Company planted both slash and loblolly pine, but there was no general agreement on where to draw the line - here slash will be most productive, but there loblolly pine will do better. We could find no clearcut answer to this question in the literature, and since it was a question with significant long-term management implications, this study was established in an attempt to provide an answer.

There were two major objectives: first, to compare the performance of slash pine (Pinus elliottii Engelm. var. elliottii) and loblolly pine (Pinus taeda L.) by testing known sources of both species on the same sites. Second, to determine whether the variation within the species was of sufficient magnitude to have practical as well as statistical significance when both species were represented by seed sources selected from and tested within a relatively restricted area.

MATERIALS AND METHODS

Each species was represented by six seed sources (Table 1). All of the seed came from large commercial collections. Most of the seedlings were grown in a single bed chosen for its uniformity in Continental Can Company's nursery near Statesboro, Ga.

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Table 1.--Slash and loblolly pine seed sources

Slash Pine	Loiblolly Pine
Baker Co., Fla.	Laurens Co., S.C.
Nassau Co., Fla.	Allendale Co., S.C.
Wayne Co., Ga.	Warren Co., Ga.
Jeff Davis Co., Ga.	Randolph Co., Ga.
Allendale Co., S.C.	Glynn, Camden, & McIntosh Co., Ga.
Emanuel & Bulloch Co., Ga.	Emanuel & Jefferson Co., Ga.

The Nassau Co., Fla. and Wayne Co., Ga., slash pine seed sources and the Randolph Co., Ga., and Glynn-Camden-McIntosh Co., Ga., loblolly pine seed sources came from other nurseries. Nursery effects upon survival and early height growth have been well established (Wakeley, 1962; Snyder and Allen, 1962). Therefore, for these seed sources, survival and growth data are confounded with nursery effects and the results cannot be considered a true measure of their potential. However, the results for specific gravity, fusiform rust infection, branchiness, and stem straightness should be independent of nursery effects.

Field planting took place during the winter of 1958-59. A 49-tree plot was used (seven rows of seven trees); spacing was 2.13 meters in the row and 2.74 meters between the rows (7' x 9').

For both species, a complete replication was made up as follows:

- (a) One plot for each of the six seed sources representing that species (one of these six is the tester in plantings of the other species).
- (b) One plot of the tester of the other species.
- (c) For convenience in planting, an eighth plot was added, using nursery run seedlings of the tester source of the predominating species.

There were four replications at all planting locations, and both species are represented in each replication at every location by means of the tester lots.

Slash pine sources were planted at five locations in the lower and middle Atlantic Coastal Plain, and loblolly pine at seven locations in the Atlantic Coastal Plain and Piedmont regions (Figure 1). All sources of both species were planted at four of the locations.

At the end of the first, third, and fifth seasons in the field, data on height, mortality, and fusiform rust infection were collected. At the end of the ninth season, data were collected on height, diameter at breast height, mortality, branchiness (the number of branches 2.54 cm. (one inch) or more in diameter between the 1.5 and 3.0 meter level above the ground), and straightness (based on an assessment of the basal seven meters of the bole; "straight" trees were those whose boles were straight enough to permit



Figure 1. Planting locations

their utilization for any purpose; "crooked" trees were those with one or more forks, three or more ramicorn branches, more than 13.2 cm. sweep per seven meters, more than three crooks per seven meters, or more than one spiral per seven meters). Data on fusiform rust infection was recorded in this fashion; on all infected trees, the number of fusiform bole galls was counted (to a maximum of 10), the number of fusiform branch galls was counted (to a maximum of 20), and trees so severely infected with fusiform rust that they appeared unlikely to survive until the time of the next measurement were recorded separately. Trees in this category were those with bole galls covering 50% or more of the circumference of the bole or with one or more smaller bole galls which also showed signs of dying. This was a subjective evaluation, of course, but it permitted a more realistic assessment of the effects of fusiform rust in trees of this age than percentage of infection or gall counts alone.

Wood samples were taken at the end of the eighth season in the field. Ten randomly selected trees per plot were sampled, eight with single bark-to-pith cores, and two with two cores per tree. The cores were taken with a ten-millemeter increment borer, and only the unextracted specific gravity was determined.

Analyses of variance were carried out for all variables. The computer program which made the analyses generated the corresponding tables of means. Duncan's multiple range procedure was used to test for significant differences (at the .05 level of significance) among the ranked means. Percentage data was transformed by the arcsin $\sqrt{\%}$ transformation, and count data by the $\sqrt{X+1/2}$ transformation (where X is the count) before analysis.

RESULTS AND DISCUSSION

The most important result of this study was that loblolly pine was significantly more productive than slash pine in the volume^{1/} and dry weight of wood produced per unit area.

In slash plantings, the loblolly tester produced 61% more volume and 54% more weight of wood than the average of the slash seed sources (Table 2). In loblolly plantings, the average of the loblolly seed sources was 49% higher for volume and 46% higher for weight than the slash tester (Table 2). In both cases, the comparisons are made on the basis of seed sources from a single nursery, i.e., excluding seed sources of either species which came from other nurseries (those whose survival and growth were poor).

Only at one location was slash pine more productive than loblolly pine. At the Baker Co., Fla., location, which was on a very poorly drained flatwoods site, slash seed sources produced an average of 24% more volume and 31% more weight of wood than the average for loblolly seed sources.

These large differences in volume and weight were the combined result of several smaller differences between the species:

^{1/} Total cubic volume inside bark.

Table 2. Slash pine seed source means for unextracted wood specific gravity, growth variables, and volume and weight of wood

Seed Source	Specific Gravity	DBH (cm.)	Height (mt.)	Percent Crooked Trees	Branches per Tree	Percent Survival	Volumes per Hectare (cu. mt.)	Weight per Hectare (1,000 kilos)
Baker Co. Fla.	.420 a	11.4 a	7.9 a	5.5 a	1.3 a	79.0 a,b	43.9 a	18.1 a
Nassau Co. Fla.	.417 a	10.5	7.0 c,d	8.4 a,b	1.3 a	43.9	17.9 b	7.5 b
Wayne Co. Ga.	.414 a	10.4	7.0 d	10.3 a,b	1.1	67.0 b	28.6 a,b	11.7 a,b
Jeff Davis Co. Ga.	.419 a	11.5 a	7.9 a	6.1 a,b	1.4 a	79.1 a,b	45.1 a	18.5 a
Eman. & Bull. Co. Ga. Sl. Tester	.414 a	11.3 a	7.9 a	7.6 a,b	1.3 a	77.4 a,b	43.4 a	17.6 a
Eman. & Bull. Co. Ga. Nur. Run	.414 a	11.0 a	7.5 b,c	6.3 a,b	1.4 a	74.9 a,b	36.7 a,b	14.8 a
Allendale Co. S.C.	.419 a	11.2 a	7.7 a,b	7.6 a,b	1.3 a	78.4 a,b	42.4 a	17.6 a
Eman. & Jeff. Co. Ga. Lob. Tester	.393	12.7	8.2 a	12.3 b	2.5	83.3 a	68.2	26.6
Means	.414	11.3	7.6	7.9	1.4	73.8	41.0	16.6

Means not marked by a common letter differ at the .05 level of significance.

(1) Loblolly seed sources had significantly higher survival than slash pine (Tables 2 and 4). When the two species were compared on the basis of seed sources from a single nursery, loblolly sources averaged 5% better survival than slash sources.

(2) In diameter at breast height, loblolly was significantly larger (1.0 to 1.5 cm.) than slash pine (Tables 2 and 4).

(3) In total height, the difference between the species was not significant, but on the average loblolly pine was slightly taller than slash pine. And height differences were greatest on the better sites (Tables 2 and 4).

Also, there was no evidence that slash pine had faster early height growth than loblolly pine, although this has often been cited as a reason for the supposed superiority of slash pine. In the slash plantings, the loblolly tester was taller than the average for the slash sources at the end of the first season, and taller than any slash source from the third season on. In the loblolly plantings, the slash tester never has ranked higher than sixth. Finally, the trend of height growth with age gives no indication that slash height growth is increasing faster than loblolly - thus there is no indication that the slash pine is likely to catch up to the loblolly pine.

It should be noted that tipmoth attacks (Ryacionia frustrana Comst.) were never serious in these tests. Attacks at the end of the first season were light (4% in slash, 18% in loblolly) and had little effect on height growth of either species. After the first season, attacks were so light and had so little apparent effect on growth that they were not recorded.

There were other differences between the species:

(1) Loblolly had significantly more branches per tree than slash pine, but differences were small, one-half to one branch per tree for the 1.5 meter section of the bole that was evaluated (Tables 2 and 4).

(2) Slash pine was significantly higher than loblolly pine in unextracted wood specific gravity, but again differences were small (.015 to .024), and this difference was completely overcome by the superior volume growth of the loblolly pine (Tables 2 and 4).

In addition, at Piedmont locations beyond the natural range of slash pine (Hancock and Saluda Co.) the specific gravity of the slash tester (.366) was lower than the average for loblolly sources at those locations (.373).

(3) In the percentage of crooked trees, the difference between the species was not significant, although slash sources averaged 3% to 4% fewer crooked trees than loblolly sources (Tables 2 and 4).

(4) In percentage infection, and mortality from fusiform rust (Cromatium fusiforme Hedgc. and Hunt ex.Cumm.), differences between the species were not significant.

But in measures of fusiform rust infection related to severity of infection (total number of galls per tree, number of bole galls per tree, percentage of trees with bole galls, and percentage of severely infected trees), slash pine was significantly higher than loblolly pine, and differences between the species were greatest at those locations where infection rates were highest (Tables 6 and 8). This suggests that even when the infection rate is the same for both species, slash pine is more likely to be severely infected than loblolly pine. It also suggests that future mortality among infected trees will be higher in slash pine than in loblolly pine. This increased mortality in slash pine is expected to accentuate differences in productivity between the species in the future.

Few meaningful differences were found among seed sources of either species in this study.

The most likely reason is that only a few sources of either species were included in this study, and these came from a restricted part of the species range. The only notable exception was the high percentage of crooked trees in the Glynn-Camden-McIntosh Co. loblolly seed source, which had an average of 29% crooked trees in comparison with an average of 11% for all seed sources in the loblolly plantings (Table 4).

Other authors, however, have reported differences in productivity among seed sources in both species. In slash pine, Gansel, et al. (1971) found significant differences in height growth among slash pine seed sources. Among those reporting significant differences among loblolly pine seed sources are Zarger (1961), Kraus (1969), Lantz and Hofmann (1969), Wells (1969), and Rink and Thor (1971).

In slash pine, no differences among seed sources in susceptibility to fusiform rust have been reported (Snyder, et al., 1967; Gansel et al., 1971). But in loblolly pine, other studies have shown considerable variation in susceptibility to fusiform rust (Wells and Wakeley, 1966; Wells and Switzer, 1971). In particular, the southeastern Louisiana loblolly source has shown a high degree of rust resistance and good growth through age 15, and has been recommended for plantings in the Coastal Plain and Piedmont of Mississippi, Alabama, and Georgia (Wells, 1969).

Thus it seems that there are significant differences among seed sources of both species whenever the sources tested are from areas where environmental factors differ significantly.

Location effects were significant in all analyses, and there were three general patterns of response.

(1) Unextracted wood specific gravity was highest in the southern Coastal Plain, decreased at locations in the northern Coastal Plain, and was lowest at Piedmont locations (Tables 3 and 5). This pattern has been reported in several studies in natural stands (Goddard and Strickland, 1962; Zobel, et al., 1960).

(2) For volume and weight of wood, diameter, height, and number of branches per tree, values were highest at locations on abandoned fields (those in Saluda Co., Hancock Co., Bleckley Co., Bulloch Co., and Jasper Co.) than at locations on prepared sites (those in Baker Co., Long Co., and Appling Co.). This seemed to be a response to site quality factors rather than a geographic effect (Tables 3 and 5).

Table 3. Location means for unextracted wood specific gravity, growth variables, and volume and weight of wood for slash pine locations

Locations	Specific Gravity	DBH (cm.)	Height (mts)	Percent Crooked Trees	Branches per Tree	Percent Survival	Volumes per Hectare (cu. mt.)	Weight per Hectare (1,000 kilos)
Baker Co. Fla.	.422 a,b	8.6 a	6.4 a	9.3 a	0.6 a	85.6 a	23.1 a	9.8 a
Long Co. Ga.	.431 a	9.3 a	6.6 a	7.9 a	0.8 a	73.4 b	24.6 a	10.6 a
Appling Co. Ga.	.419 b	9.3 a	6.8 a	0.7	0.9 a	84.4 a	27.1 a	11.3 a,b
Bulloch Co. Ga.	.397 c	15.9	10.1	22.5	3.2 b	70.3 b	92.2	36.4
Jasper Co. S.C.	.399 c	13.2	8.3	6.0 a	2.6 b	47.6	37.8	15.0 b
Means	.414	11.3	7.6	7.9	1.4	73.8	41.0	16.8

Means not marked by a common letter differ at the .05 level of significance.

Table 4. Loblolly pine seed source means for unextracted wood specific gravity, growth variables, and volume and weight of wood

Seed Source	Specific Gravity	DBH (cm.)	Height (mt.)	Percent		Branches per Tree	Percent Survival	Volumes per Hectare		Weight per Hectare (1,000 kilos)
				Crooked Trees				(cu. mt.)		
Laurens Co. S.C.	.387 a	12.6 a	7.9 a,b	7.4 a,b		3.4 a,b	76.4 a,b	51.2 a,b		19.7 a,b
Allendale Co. S.C.	.386 a	12.5 a	7.9 a,b	9.5 a,b		3.5 a,b	75.3 a,b	51.5 a,b		19.7 a,b
Warren Co. Ga.	.388 a	12.5 a	8.1 a,b	5.8 b		3.3 b	79.3 a	56.4 a		21.6 a
Eman. & Jeff. Co. Ga. Lob. Tester	.382 a	12.9 a	8.2 a	9.5 a,b		3.1 a	78.2 a	58.9 a		22.3 a
Eman. & Jeff. Co. Ga. Nur. Run	.383 a	12.9 a	8.2 a	9.8 a,b		3.1 a	74.2 a,b	55.8 a,b		21.2 a
Randolph Co. Ga.	.382 a	11.9 a,b	7.2 b	12.2 a		3.3 a,b	70.0 b	41.8 c		15.7 b,c
G-C-M Co. Ga.	.379 a	12.3 a,b	7.8 a,b	29.2		2.6	69.8 b	46.0 b,c		17.2 b,c
Eman. & Bull. Co. Ga. Sl. Tester	.399	11.5 b	7.5 a,b	7.8 a,b		1.8	71.6 a,b	36.6 c		14.3 c
Means	.386	12.4	7.9	10.7		3.0	74.5	49.8		19.0

Means not worked by a common letter differ at the .05 level of significance.

Table 5. Location means for unextracted wood specific gravity, growth variables, and volume and weight of wood for loblolly pine locations

Location	Specific Gravity	DBH (cm.)	Height (mt.)	Percent Crooked Trees	Branches per Tree	Percent Survival	Volumes per Hectare (cu. mt.)	Weight per Hectare (1,000 kilos)
Baker Co. Fla.	.397 c	7.7 a	5.3	11.0 a	0.9 a	90.2 a	18.6 a	7.4 a
Long Co. Ga.	.412 c	9.0 a	6.3 c	12.6 a	1.3 a	83.9 b	28.1 a,b	11.6 a,b
Appling Co. Ga.	.389 b,c	9.3 a	6.6 c	1.5	1.5 a	93.1 a	29.9 a,b	11.7 a,b
Jasper Co. S.C.	.386 b	15.1 b,c	9.6 a	15.5 a	3.1	56.0 c	68.2 d	26.2 d
Bleckley Co. Ga.	.371 a	16.2 b	8.5 b	16.5 a	8.1	35.7	40.9 b,c	15.2 b,c
Hancock Co. Ga.	.371 a	14.2 c	8.7 b	8.7 a	4.2 b	62.4 c	55.1 c,d	20.4 c,d
Saluda Co. S.C.	.374 a	15.6 b	10.2 a	14.5 a	4.7 b	83.4 b	107.3	40.2
Means	.386	12.4	7.9	10.7	3.0	74.5	49.8	19.8

Means not marked by a common letter differ at the .05 level of significance.

Table 6. Slash pine seed source means for measures of fusiform rust infection

Seed Source	Percent Mortality	Percent Infection	No. bole		No. Branch		Total No. Galls per Tree	Percent		Percent		Percent Severely Infected
			Galls per Tree		Galls per Tree			Bole Galls		Branch Galls		
Baker Co. Fla.	8.2 a	46.4 a,b	0.9 a		2.5 a		2.8 a	17.2 a		38.3 a		9.2 a
Nassau Co. Fla.	2.4 b	39.7 a,b	0.9 a		2.0 a,b		2.3 a	21.4 a		33.6 a		8.2 a
Wayne Co. Ga.	4.1 b,c,d	43.6 a,b	0.9 a		2.1 a		2.4 a	22.7 a		38.7 a		9.9 a
Jeff Davis Co. Ga.	6.4 a,d	49.1 a	0.9 a		2.2 a		2.5 a	20.9 a		37.1 a		9.1 a
Eman. & Bull. Co. Ga. Sl. Tester	8.2 a	49.8 a	0.9 a		2.2 a		2.5 a	21.8 a		44.5 a		8.9 a
Eman. & Bull. Co. Ga. Nur. Run	3.0 b,c	48.8 a	0.8 a,b		2.2 a		2.5 a	21.6 a		43.9 a		9.5 a
Allendale Co. S.C.	8.2 a	41.4 a,b	0.9 a		2.1 a		2.4 a	22.5 a		38.6 a		10.8 a
Ema. & Jeff. Co. Ga. Lob. Tester	5.1 a,c,d	36.5 b	0.7 b		1.5 b		1.7	12.6 a		32.0 a		3.7
Means	5.5	44.4	0.9		2.1		2.4	19.9		38.3		8.5

Means not marked by a common letter differ at the .05 level of significance.

(3) For all measures of fusiform rust infection, values were highest at locations on abandoned fields, and lower at locations on prepared sites (Tables 7 and 9). It has long been recognized that plantations or natural stands on abandoned fields are more severely infected than those on undisturbed sites in the same area (Siggers, 1955).

There was also an indication of a geographic effect, since the extreme north and south locations were significantly lower in most measures of fusiform rust infection than locations in the center of the test area.

In summary, this study showed that loblolly pine was significantly more productive than slash pine in the volume and weight of wood produced in the area where the study was conducted. These results are based on measurements at the end of the ninth season, and these species aren't usually harvested before an age of 20-30 years. Thus, the results and conclusions are tentative, and must be confirmed by future measurements before they can be considered final.

However, evidence from the data on height growth and fusiform rust infection is such that there is little indication that any major reversal will take place; it seems more likely that differences in productivity will be greater in the future.

The difference in productivity is certainly large enough to have considerable economic importance. It favors the use of loblolly pine on well drained sites over a large part of the southeastern Coastal Plain, although slash pine will be more productive on poorly drained sites.

It is suggested that forest land managers within that part of the natural range of slash pine covered by this study may obtain an economically important increase in productivity by planting the appropriate source of loblolly pine, instead of slash pine, on the better drained sites.

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Table 7. Location means for measures of fusiform rust infection for slash pine locations

Location	Percent Mortality	Percent Infection	No. Bole Galls per Tree	No. Branch Galls per Tree	Total No. Galls per Tree	Percent Bole Galls	Percent Branch Galls	Percent Severely Infected
Baker Co. Fla.	1.4 a	1.3	0.5	0.5	0.5	0.1	0.7	0.0
Long Co. Ga.	4.1	36.6 a	0.6 a	1.1	1.2	11.8 a	31.5 a	4.3
Appling Co. Ga.	2.3 a	30.9 a	0.6 a	0.9	1.0	7.3 a	27.2 a	2.2
Bulloch Co. Ga.	6.2	81.4 b	1.3	5.2 a	6.0 a	47.8	72.2 b	20.7
Jasper Co. S.C.	21.3	87.7 b	1.6	5.3 a	6.4 a	63.3	81.2 b	39.3
Means	5.5	44.4	0.9	2.1	2.4	19.9	38.3	8.5

Means not marked by a common letter differ at the .05 level of significance.

Table 8. Loblolly pine seed source means for measures of fusiform rust infection

Seed Source	Percent Mortality	Percent Infection	No. Bole		No. Branch		Total No. Galls per Tree	Percent		Percent Branch Galls	Percent Severely Infected
			Galls per Tree		Galls per Tree			Bole Galls			
Laurens Co. S. C.	1.6 a	42.4 a,b	0.7 a,b		1.8 a		2.0 a	15.3 a,b		38.3 a,b	2.5 a
Allendale Co. S. C.	2.5 a	45.6 a,b	0.7 a,b		1.8 a		2.1 a	14.5 a,b		41.4 a,b	3.3 a
Warren Co. Ga.	2.6 a	43.1 a,b	0.7 a,b		1.7 a		1.9 a	13.4 a,b		39.7 a,b	2.1 a
Eman. & Jeff. Co. Ga. Lob. Tester	4.5 a	42.9 a,b	0.8 a,b,c		1.8 a		2.0 a	15.7 a,b		39.8 a,b	2.6 a
Eman. & Jeff. Co. Ga. Nur. Run	1.9 a	48.9 a	0.8 a,c		2.0 a		2.2 a	18.9 a,c		43.4 a	2.3 a
Randolph Co. Ga.	4.4 a	44.7 a,b	0.8 a,b,c		1.9 a		2.2 a	16.6 a,b		38.0 a,b	3.1 a
G-C-M Co. Ga.	2.1 a	37.8 b	0.7, a,b		1.6 a		1.8 a	12.8 a		32.0 b	2.2 a
Eman. & Bull. Co. Ga. Sl. Tester	4.8 a	46.6 a	0.9 c		1.7 a		2.1 a	22.8 c		38.6 a,b	8.5
Means	3.0	44.0	0.8		1.8		2.0	16.2			3.1

Means not marked by a common letter differ at the .05 level of significance.

Table 9. Location means for measures of fusiform rust infection for loblolly pine locations

Location	Percent Mortality	Percent Infection	No. Bole		No. Branch		Total No. Galls per Tree	Percent Bole Galls	Percent Branch Galls	Percent Severely Infected
			Galls per Tree	Galls per Tree	Galls per Tree	Galls per Tree				
Baker Co. Fla.	1.5 a, b	2.8	0.5 a	0.5	0.5	0.5	0.4	2.1	0.1 a	
Long Co. Ga.	1.2 a,b	20.6 a	0.6 a	0.8 a	0.8 a	0.9 a	4.6 a	18.7 a	1.5 b	
Appling Co. Ga.	1.0 a	18.4 a	0.6 a,b	0.8 a	0.8 a	0.8 a	4.6 a	16.0 a	0.7 a,b	
Jasper Co. S.C.	7.4 c	83.9 b	1.2 d	4.3	4.3	5.0	49.8 c	77.2 c	21.7	
Bleckley Co. Ga.	3.1 b	79.4 b	1.1 c,d	3.7 b	3.7 b	4.3 b	41.0 b,c	74.6 b,c	6.2 c	
Hancock Co. Ga.	6.4 c	77.4 b	1.0 c	3.4 b	3.4 b	3.9 b	34.2 b	70.1 b	6.1 c	
Saluda Co. S. C.	2.8 a,b	40.1	0.7 b	1.2	1.2	1.3	12.8	34.9	0.1 a	
Means	3.0	44.0	0.8	1.8	1.8	2.0	16.2	39.0	3.1	

Means not marked by a common letter differ at the .05 level of significance.

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PERFORMANCE OF INTERSPECIFIC HYBRIDS
AND EXOTIC PINES IN TEXAS

by

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Abstract: Exotic and hybrid pines have been tested in Texas as part of the Forest Tree Improvement Program of the Texas Forest Service. Some of the oldest test plantations are approximately 20 years old. Survival has been poor due to climatic factors and endemic insect attack. In general none of the exotic species tested have responded favorably to their new environment and none have grown better than native southern pines. Species which have shown good survival and growth include some of the minor southern pines not native to Texas. Species which have had very poor survival or growth include species from Mexico, Europe, Asia, and the Western United States.

A part of the project involved controlled interspecific hybridization of the major southern pines and selected exotic species. The slash-longleaf hybrid has shown the most promise of any hybrids tested. Hybrids between most exotic species have had poor survival, but hybrids between the southern pines have survived and grown well.

INTRODUCTION

When the Tree Improvement Program of the Texas Forest Service was initiated in 1951, a part of the program was devoted to testing hybrids and exotics for possible use in Texas. A test arboretum was established in which pine hybrids and as many exotic pine species as possible were included. In addition to the arboretum a limited number of hybrids and exotics were field planted at two test sites in Central Texas. A test arboretum was also established in Western Louisiana but will not be discussed in this paper.

Because of the success exotics have had in other countries, especially Australia, Africa, and South America and the success of pine hybridization programs in South Korea, the search for a better tree to plant in East Texas and especially in the transitional zone of pine forest to post oak and prairie on the western edge of the southern pine forest, is appealing.

In a 1956 progress report, the performance of hybrids and exotics during their early establishment phase in the nursery and in the field was discussed (Zobel *et al.* 1956). Since that time the relative performance of many of the species and hybrids tested have been influenced by a wide variety of weather extremes encompassing most conditions to which native species are adapted.

METHODS

Test plantings were established at three locations in Texas. One of the sites is the Arthur Temple Research Area in Cherokee County, well within the western edge of the southern pine forest.* This location has approximately 44 inches of annual rainfall, with an approximate 95° 30' longitude and about 32° 30' latitude. Adjacent stands of commercial forest land appear to be on about a 90+ site index. Typical winters are wet with an abrupt transition from winter into a hot dry spring. Summer temperatures may exceed 110° with low relative humidity and winter temperatures are mild and rapidly fluctuating with mid-winter warm (65-70°F) periods followed by sudden cold weather (20-30°F) common.

A second outplanting was made at the Ragesdale Research Area in Lavaca County. This site is about 100 miles west and 50 miles south of the normal western limits of the southern pines. It is a severe test site with deep sandy soil and about 38 inches of annual rainfall. The longitude is about 97° and latitude about 29° 30'. Adjacent timber stands are predominately post and live oak with some elm, yaupon, hackberry, and mesquite. No commercial timber is grown in the vicinity.

The third outplanting was made at the Lange Research Area in Robertson County. This area is approximately 50 to 75 miles west of the edge of the southern pine forest. The site is on deep sand in a region of about 38 inches of annual rainfall near longitude 96° 30' latitude 31°.

Again, as with the Ragesdale Area, no commercial timber is produced in the area. Adjacent timber stands consist of post and sand jack oak, hackberry, mesquite and various elms. On both the Ragesdale and Lange areas, hybrids and exotics were established in small plantings in conjunction with drought resistance tests of loblolly pine. The plantings consisted of those species in which an excess of seedlings above those required for the main test arboretum were available, thus the main value of both areas has been to reinforce observations made at the Temple area.

On the Temple Research Area about 75 species and varieties of pines were planted in an exotic arboretum. These included species from the Appalachian Region, the South, Southwest, West Coast and Lake States in the United States and from Canada, Japan, China, North and Central Mexico, Canary Islands, Phillippines, Mediterranean Region and Europe. Plots were usually 10 x 10 feet, 49 tree blocks if enough seedlings were available, if not, the block size was reduced.

On both the Ragesdale and Lange areas smaller plots were used. Plant-

* Loblolly (*Pinus taeda* L.), shortleaf (*P. echinata* Mill.) and longleaf pine (*P. palustris* Mill.) occur naturally in the Texas portion of the southern pine forest while slash pine (*P. elliotii* Engelm.) has been widely planted for over 25 years.

ings were usually row plots with a few small blocks. Spacings were usually 6 x 8 feet. Both of these areas are test centers for drought resistant loblolly pine and exotics and hybrids were made in conjunction with drought resistance tests. Since relatively small numbers and few species and hybrids were planted on these Central Texas areas, the information obtained is less complete but supported that obtained on the Temple Area in East Texas.

Most plantations were established during the 1953-54 or 1954-55 planting seasons.

RESULTS

Exotics

Most exotics from outside the South have had a low survival and growth rate on all three areas. Many of those which have survived have poor form and low vigor. Repeated attacks by endemic insects have caused some of the surviving individuals to virtually stop growing. The exact cause of death is not known in most cases but is assumed to be the result of a combination of factors.

In some instances seed failed to germinate after planting in the nursery and this was attributed to the sudden onset of summer with its attendant high temperatures (Zobel, et al. 1956). Even with native loblolly pine this abrupt transition from cold to hot can cause germination failures of seed planted late in the spring.

Another cause of failure was seedling death attributed to hot summer weather after establishment in the nursery beds (Zobel, et al. 1956). There are periods of extremely high light intensity which may combine with the high summer heat to cause seedling death.

After outplanting in the test arboretum or in the Central Texas test sites, the cause of failure is usually more difficult to ascertain. For some species it seems to have been due to a lack of synchrony with the photoperiodicity at the planting site and periods of warm winter weather followed by abrupt changes to cold weather. The high light intensities of late winter combined with unseasonable warm weather met the species requirement for initiation of spring growth. After new growth had started the trees were extremely susceptible to cold and were often subjected to below freezing temperatures for several days.

The intense summer heat combined with summer drought undoubtedly took a heavy toll of young trees for the first few years after outplanting. A more gradual attrition followed and was due to a combination of heat, low humidity, drought, severe planting sites and failure of species to adjust to new photoperiodic regimes combined with abrupt temperature changes.

Whatever the factor or combination of factors were that caused failure of most exotics the result has been the complete decimation of many species while many of those which survived are stunted and malformed.

Some exotics from within the South have shown some promise or at least have been able to survive and grow with reasonable success. There has been a non-uniform response to environment by seedlots from different areas within a region. This response is similar to that of different seed lots reported in the geographic seed source study (Wells and Wakely 1966)

Exotics planted at the Temple Research Area are listed in Table I. All common and species names follow Critchfield and Little 1966.

Hybrids

The performance of hybrids has more or less paralleled the performance of exotics. Hybrids resulting from crosses between parents from outside the South have survived poorly. A partial listing of hybrids planted at the Arthur Temple Research Area is included in Table II.

The best hybrids have been those involving the major southern pines. In most cases these have not approached either parent as desirable forest trees because of poor form, excessive limbs, or various other reasons including slower growth. A hybrid which has shown promise is a polymix cross of slash x longleaf which has exhibited excellent growth rate, form, and limb characteristics.

CONCLUSIONS

After approximately 20 years of field testing most exotics tested have shown little promise for potential use in replacing any of the four major southern pines as planting or reforestation stock either within the pine forest of East Texas or in the transition zone of scrub hardwoods west of the pine forest.

The minor southern pines, specifically P. clausa (Chapm.) Vasey, P. serotina Michx., P. glabra Walt. and P. virginiana Mill. have grown and survived well in East Texas but have not survived well on the two Central Texas sites. P. glabra and P. clausa have the best survival and growth of any of the exotics tested. P.seudostrobus Lindl. and P. durangensis Martinez, two Mexican sources, have the best survival and growth of any sources from outside the South.

Most species which were surviving and showing promise at four or five years have gradually failed because of the combined effects of heat, cold, rapid temperature changes, photoperiod and endemic insects and diseases.

TABLE I

Partial list of pine species planted at Temple Research Area

<u>Species</u>	<u>Common Name</u>	<u>Percent Survival</u>
<u>P. armandii</u> Franch.	Armand pine	0
<u>P. attenuata</u> Lemm.	knobcone pine	0
<u>P. ayacahuite</u> Ehrenb.	Mexican white pine	0
<u>P. barksiana</u> Lamb.	Jack pine	0
<u>P. canariensis</u> C. Smith	Canary Island pine	0
<u>P. caribaea</u> Morelet	Caribbean pine	0
<u>P. cembroides</u> Zucc.	Mexican pinyon pine	0
<u>P. clausa</u> (Chapm.) Vasey	sand pine	56
<u>P. contorta</u> Dougl.	lodgepole pine	0
<u>P. cooperi</u> C.E. Blanco	Cooper pine	0
<u>P. coulteri</u> D. Don	Coulter pine	0
<u>P. densiflora</u> Sieb. & Zucc.	Japanese red pine	9
<u>P. douglasiana</u> Martinez	Douglas pine	0
<u>P. durangensis</u> Martinez	Durango pine	32
<u>P. edulis</u> Engelm.	pinyon pine	0
<u>P. elliotii</u> var. <u>densa</u> Little & Dorman	South Florida slash pine	0
<u>P. engelmannii</u> Carr.	Apache pine	41
<u>P. glabra</u> Walt.	spruce pine	61
<u>P. griffithii</u> McClelland	blue pine	0
<u>P. halepensis</u> Mill.	Aleppo pine	0
<u>P. hartwegii</u> Lindl.	Hartweg pine	0
<u>P. jeffreyi</u> Grev. & Balf.	Jeffrey pine	0
<u>P. leiophylla</u> Schiede & Deppe	Chihuahua pine	0
<u>P. luchensis</u> Mayr	Okinawan pine	0
<u>P. lumholtzii</u> Robins & Fern.	Lumholtz pine	0
<u>P. massoniana</u> Lamb.	Masson pine	0
<u>P. michoacana</u> Martinez	Michoacan pine	0
<u>P. montezumae</u> Lamb.	Montezuma pine	16
<u>P. monticola</u> Dougl.	western white pine	0

TABLE I - Continued

<u>Species</u>	<u>Common Name</u>	<u>Percent Survival</u>
<u>P. mugo</u> Turra	Swiss Mountain pine	0
<u>P. muricata</u> D. Don	Bishop pine	0
<u>P. nigra</u> Arnold	Austrian pine	0
<u>P. oocarpa</u> Schiede	(unknown)	0
<u>P. patula</u> Schiede & Deppe	Mexican weeping pine	0
<u>P. pinaster</u> Ait.	maritime pine	0
<u>P. pinea</u> L.	Italian stone pine	0
<u>P. ponderosa</u> Laws (& varieties)	ponderosa pine	0
<u>P. pseudostrobus</u> Lindl.	(unknown)	40
<u>P. pungens</u> Lamb.	Table-Mountain pine	12
<u>P. radiata</u> D. Don	Monterey pine	0
<u>P. resinosa</u> Ait.	red pine	0
<u>P. roxburghii</u> Sarg.	chir pine	0
<u>P. sabiniana</u> Dougl.	digger pine	0
<u>P. serotina</u> Michx.	pond pine	57
<u>P. sylvestris</u> L.	Scotch pine	0
<u>P. strobiformis</u> Engelm.	southwestern white pine	0
<u>P. strobus</u> L.	eastern white pine	0
<u>P. teocote</u> Schiede & Deppe	(unknown)	0
<u>P. thunbergiana</u> Franco	Japanese black pine	14
<u>P. virginiana</u> Mill.	Virginia pine	68
<u>P. yunnanensis</u> Franch.	Yunnan pine	0

TABLE Ia

Average height and diameter of the better exotic pine species after approximately 20 years.

<u>Species</u>	<u>Avg. DBH</u>	<u>Height</u>	<u>Percent Survival</u>
<u>P. clausa</u>	11.2	43.5	56
<u>P. durangensis</u>	9.4	34.2	32
<u>P. glabra</u>	9.5	40.5	61

TABLE Ia - continued

<u>Species</u>	<u>Avg. DBH</u>	<u>Height</u>	<u>Percent Survival</u>
<u>P. pseudostrobus</u>	8.3	30.0	40
<u>P. serotina</u>	10.1	39.0	57
<u>P. virginiana</u>	8.0	32.3	68

TABLE II

Partial list of hybrids and checks planted at Temple Research Area approximately 20 years after planting.¹

<u>Hybrid</u>	<u>Avg. DBH</u>	<u>Height</u>	<u>Percent Survival</u>
<u>P. echinata</u> (open pollinated)	7.1	41.0	75
<u>P. echinata</u> x <u>P. elliotii</u>	8.2	34.1	100
<u>P. taeda</u> (open pollinated)	11.4	53.6	83
<u>P. echinata</u> x <u>P. sondereggeri</u>	11.3	59.8	100
<u>P. taeda</u> x <u>P. sondereggeri</u>	11.0	52.0	75
<u>P. taeda</u> x <u>P. elliotii</u>	10.8	55.7	41
<u>P. taeda</u> x <u>P. radiata</u>	9.5	48.8	85
<u>P. ponderosa</u> x <u>P. apachea</u>	0	0	0
<u>P. ponderosa</u> x <u>P. montezumae</u>	0	0	0
<u>P. palustris</u> x <u>P. elliotii</u>	8.0	50.0	90
<u>P. palustris</u> x <u>P. elliotii</u> 1961 ²	5.9	40.0	60
(<u>P. echinata</u> x <u>P. taeda</u>) x wind lot 10	10.1	40.0	84
(<u>P. echinata</u> x <u>P. elliotii</u>) x <u>P. taeda</u>	11.4	52.0	40
(<u>P. echinata</u> x <u>P. taeda</u>) x <u>P. taeda</u>	9.5	50.0	33
<u>P. echinata</u> x (<u>P. echinata</u> x <u>P. elliotii</u>)	8.1	49.1	58
(<u>P. echinata</u> x <u>P. elliotii</u>) x wind	5.9	38.3	33
<u>P. taeda</u> x (<u>P. echinata</u> x <u>P. elliotii</u>)	8.1	53.6	55
(<u>P. taeda</u> x <u>P. elliotii</u>) x <u>P. elliotii</u>	10.3	46.6	66

¹Block sizes are highly variable and sources are not replicated. These data can serve only as an indicator of performance of different hybrids tested and are not suitable for detailed comparison or analysis.

²Planted in 1961; average of all crosses. The different parental combinations have survivals ranging from 47 to 84 percent.

Hybrid survival and growth depends on the parental species. Hybrids from exotic parents have not survived well -- almost all died within the first 10 years. Conversely, those hybrids formed by crossing southern pines have had high survival rates and reasonably good growth. Most combinations do not produce progeny comparable in growth or quality to the parental types. An exception to this seems to be the slash x longleaf hybrid which, at 12 years in the field seems to have many of the desirable traits of both parents.

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PROSPECTS FOR USING NATURAL LOBLOLLY x SHORTLEAF HYBRIDS
FOR RESISTANCE TO FUSIFORM RUST

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Abstract.--Natural hybridization of loblolly pine (Pinus taeda L.) and shortleaf pine (Pinus echinata Mill.) has been suggested as the probable cause of resistance to fusiform rust (Cronartium fusiforme Hedge and Hunt) in western provenances of loblolly pine. Phenology studies of loblolly and shortleaf pines in East Texas have indicated an overlap in pollen shed of the two species.

From a hybrid index based on five morphological characters, trees with characteristics intermediate to the two species have been detected.

Investigations are currently underway to determine what implications such introgression may have with respect to rust resistance and the possible uses of this source of natural resistance.

Additional keywords: phenology, hybrid index, numerical classification, sample sizes.

INTRODUCTION

The existence of phenotypes intermediate to both species has been observed within mixed natural populations of loblolly (Pinus taeda L.) and shortleaf (P. echinata Mill.) pines in East Texas (Zobel, 1953; Bilan, 1965). Should these intermediate types possess the acknowledged resistance to fusiform rust (Cronartium fusiforme Hedge and Hunt) exhibited by shortleaf pine (Snow and Kais, 1970) and the more desirable growth characteristics inherent in loblolly pine, identification and selection of these intermediates could represent a gene pool containing desirable recombinants.

Work by Dorman and Barber (1956) concluded that both loblolly and shortleaf were releasing pollen concurrently between March 20 and March 26 in 1951, in Nacogdoches County, Texas. Hicks, et al. (1972) confirmed this possibility in the same area in 1971. Twenty sexually mature trees of each species were monitored from February 12 to April 27. Results showed that 10 percent of the shortleaf pines under observation were producing pollen simultaneously with more than half of the loblolly pines. Since female strobili are normally receptive shortly following first pollen release, phenological opportunity exists for interspecific crosses.

This paper describes current research at the School of Forestry, Stephen F. Austin State University² designed to establish means for

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²Located in Nacogdoches, Texas. Research under the direction of Dr. Ray Hicks, Jr. and supported in part by the McIntire-Stennis Act.

identifying loblolly x shortleaf hybrids with resistance to fusiform rust, which could be incorporated into a tree improvement program.

SELECTION OF TAXONOMIC TRAITS AND WITHIN-TREE SAMPLE SIZES

Hicks (In press) tested 12 morphological characteristics among shortleaf, loblolly, and putative hybrids. His analysis was based upon a numerical taxonomic classification method proposed by Flake and Turner (1968). No attempt was made to evaluate environmental influence upon the traits. Table 1 shows the resulting estimates (using Stein's two-stage sample technique) of sample size required to measure each character within ± 5 percent of true mean (Steel and Torrie, 1960). Characters involving difficult determinations, or very large samples were considered least suitable for taxonomic determinations. Among the morphological characteristics examined, those which appeared best suited for segregating these taxa were needle length, fascicle sheath length, number of needles per fascicle, terminal bud width, and cone length.

Table 1. Sample size required to estimate within-tree means within $\pm 5\%$ of the true mean.

Character	Number of Samples Required	
	t = 90%	t = 95%
Needle length	17 needles	28 needles
Needle width	113 needles	192 needles
Fascicle sheath length	10 fascicles	18 fascicles
No. of needles per fascicle	31 fascicles	52 fascicles
No. of stomatal rows	67 needles	118 needles
No. of stomates per cm in rows	12 needles	20 needles
Terminal bud length	42 buds	82 buds
Terminal bud width	53 buds	102 buds
Axillary scale width	715 scales	1,210 scales
Cone length	26 cones	45 cones
Cone width	97 cones	169 cones
Seed weight	*	*

*The within-tree sample size could not be calculated for seed weight due to the original sampling technique, i.e. a single within-tree sample.

Table 2 demonstrates the correlation coefficients (r) derived for the 12 traits. Hybrids of two different species should produce progeny which are intermediate for quantitative traits; thus characters which reflect genetic differences in the parental species should possess genetic correlations in an introgressed population. High (r) values could result from environmental effects; therefore should not be taken as an absolute measure of taxonomic worth. Low (r) values demonstrate little worth of a trait for taxonomic purposes.

Table 2. Matrix consisting of correlation coefficients (r) derived from all possible combinations of tree-mean values for morphological characters observed (after Hicks, 1971).

	Needle Length	Needle Width	Needle Length	No. of Stomates Per cm in Rows	No. of Stomates Per Fascicle	Fascicle Sheath Length	No. of Needles Per Fascicle	Terminal Bud Length	No. of Stomatal Rows	Terminal Bud Width	Axillary Scale Width	Cone Length	Cone Width	Seed Weight
Needle Length														
Needle Width	.821**													.719**
No. of Stomates Per Cm In Rows	.018ns	.858**												.631**
Fascicle Sheath Length	.350*	.788**	.821**											.696**
No. of Needles Per Fascicle		.172ns	.139ns	.842**										.070ns
Terminal Bud Length			.856**	.039ns	.215ns	.722**	.894**	.895**	.728**	.113ns	.070ns	.654**	.689**	.661**
No. of Stomatal Rows			.821**	.641**	.597**	.233ns	.170ns	.857**	.709**	.728**	.620**	.310*	.369*	.369*
Terminal Bud Width			.139ns	.159ns	.793**	.829**	.861**	.689**	.314*	.288*	.217ns	.245ns	.575**	.575**
Axillary Scale Width			.842**	.493**	.312*	.752**	.712**	.337*	.634**	.774**	.680**	.762**	.883**	.797**
Cone Length				.501**	.265ns	.294*	.395**	.849**						
Cone Width														
Seed Weight														

** From the estimated value of r, it can be concluded that the population correlation coefficient is significantly different from 0 at the 0.1 level.

* Significant at the 0.05 level.

ns Not significant at the 0.05 level.

FREQUENCY OF INTERSPECIFIC HYBRIDS WITHIN NATURAL STANDS IN EAST TEXAS

In the fall of 1971, samples were collected from 164 trees in 16 stands in East Texas for the purpose of determining the frequency of natural hybridization between loblolly and shortleaf pines (Cotton, 1972). Three basic mathematical techniques were applied to determine how intermediate types might be differentiated within a natural population based upon correlated morphological traits.

Samples of cones, buds, and needles were measured for five morphological traits. These were cone length, terminal bud width, sheath length, needle length, and the number of needles per fascicle.

Following derivation of within-tree means for each character, tree-mean values of the trees exhibiting the minimum and maximum raw measurements for each trait were assigned scores of 0.0 and 5.0, respectively. The mean values for other individuals were transformed to a linear scale of 0.0 to 5.0 by interpolation. These scores were then used for analysis by hybrid index (Anderson, 1949), cluster analysis (Veldman, 1967), and factor analysis (Lawley and Maxwell, 1963).

Figure 1 shows the frequency distribution of individuals by hybrid index scores with three cluster analysis groups given letter designations (Hicks, *et al.*, 1973). The distribution indicates two distinct, normally distributed populations representing loblolly and shortleaf pine. Morphologically intermediate trees were present but appeared to be normal deviates of their respective parental populations.

The fact that three cluster analysis groups exist does not necessarily imply that the intermediates are natural hybrids. Due to the nature of the technique, any specified number of cluster groups will be formed at some level.

Principal component analysis (Figure 2) developed two component factors, one of which accounted for almost 99% of the total variation in the five morphological traits.

The bulk of the evidence at this point indicates that there is little justification for claiming widespread introgression among loblolly and shortleaf pines. Isoenzyme analysis of seed proteins of trees with a range of morphological types conceivably should be beneficial in establishing whether hybridity is the source of some morphological variability. The latter observation has prompted the beginning of isoenzyme studies by electrophoresis in the near future.

TESTING FOR RUST RESISTANCE

Preparation for further testing began in the fall of 1972 when needle, bud, and mature cone samples were collected from 52 trees at four locations within a sixty-mile radius of Nacogdoches (Florence, 1973). Trees sampled were selected on the basis of their position on the hybrid index scale employed by Cotton (1972). Trees ranging from

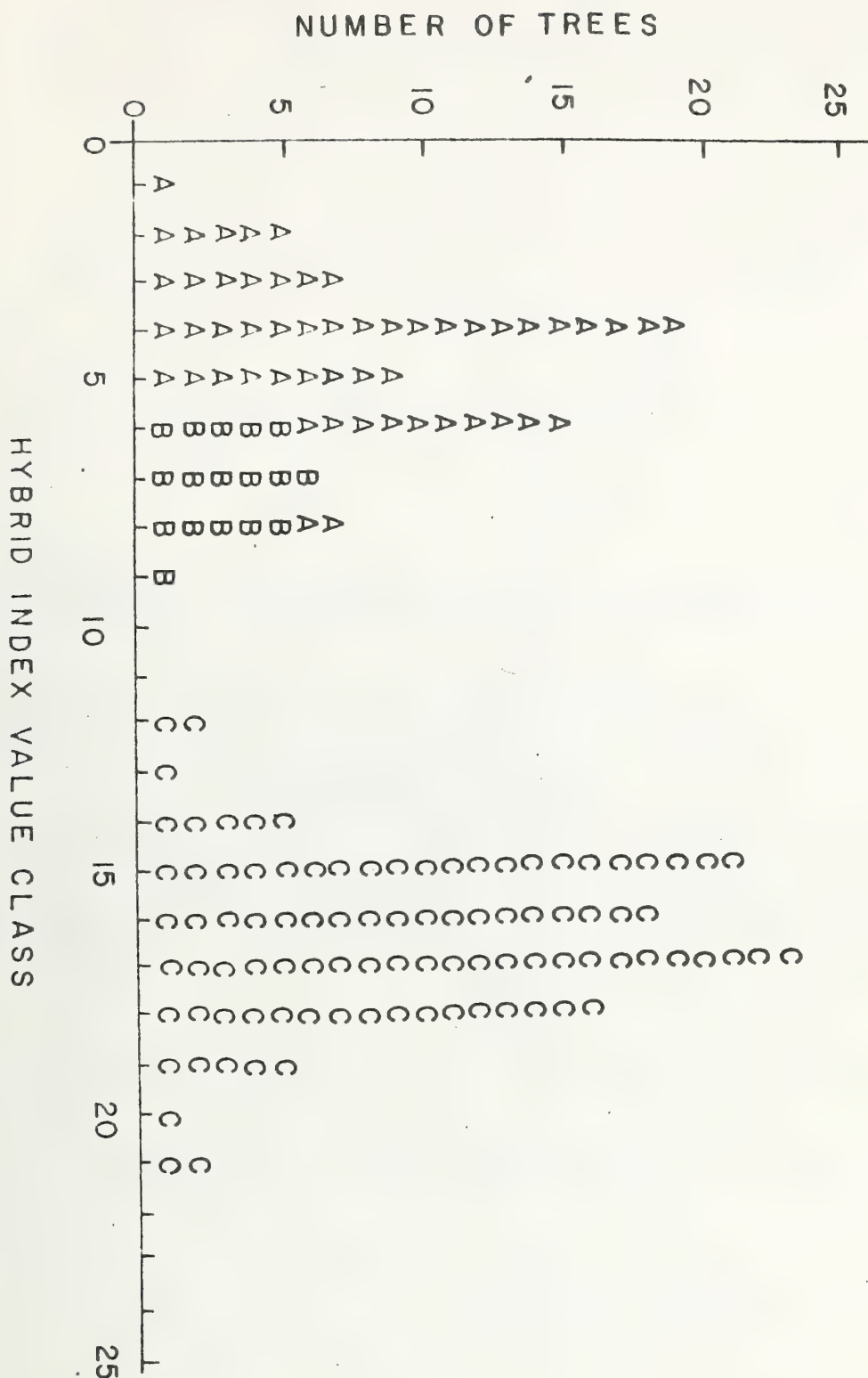


Figure 1. Frequency distribution of the sample population based on hybrid index values. Letter designations indicate cluster analysis groups. (Plotting by Hicks, from data by Cotton, 1972).

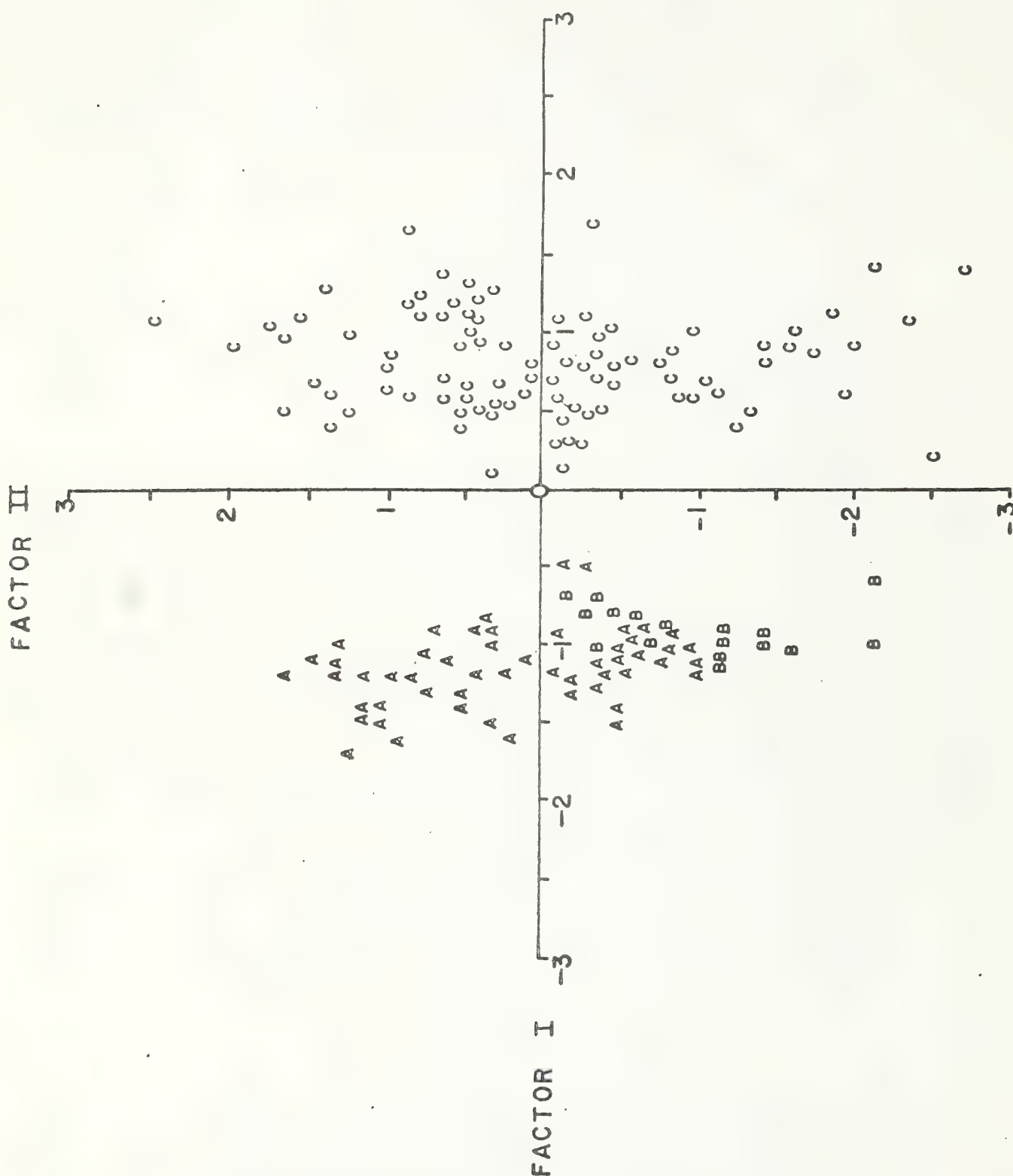


Figure 2. Plotting of the sample population by principal axis factor scores from principal components analysis. Letter designations indicate cluster groupings of individuals into three cluster groups. (Plotting by Hicks, from data by Cotton, 1972).

shortleaf types to loblolly types, including intermediates, were sampled.

Seed from the 1972 samples were extracted, cleaned, and stratified during the past winter. Fifteen half-sib family lots of each subjective group (45 lots total) have been submitted for testing in this year's fusiform rust trials conducted at the U. S. Forest Service's Forest Pest Management facilities at Asheville, North Carolina. Herein lies the prime objective of the current study.

At this point in our research at Stephen F. Austin State University we wish to culminate what has been learned of the East Texas pine population into a manageable framework of information. Hopefully, such a framework will permit us to select for loblolly types with greater surety of a resistant individual's genotype.

Subsequent testing is planned to reinforce this goal through progeny tests conducted in controlled greenhouse studies and electrophoretic protein separations. Each of these studies will include use of these same 45 families soon to be tested for their resistance to fusiform rust.

SUMMARY

Sequential research of shortleaf and loblolly pine in East Texas at Stephen F. Austin State University during the past three years has shown their phenology to permit natural crossing.

Based upon five correlated morphological characteristics, it has been concluded that natural hybrids are infrequent in the natural population if morphological characters are good indicators of such hybrids.

Current research is devoted to determining to what extent intermediates may express resistance to fusiform rust as compared to parental types. Concurrently, studies are in progress to more fully develop the progeny morphology and biochemical relationships to rust resistance as an addendum to practical field selection from the natural parental population.

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SHOULD SLASH PINE SEED ORCHARDS BE MOVED
SOUTH FOR EARLY FLOWERING?

Charles R. Gansel^{1/}

Abstract.--In two slash pine seed source study plantations, trees from northern sources produced cones earlier than those from southern sources. As the plantations increased in age, more southern sources started cone production. Conelet production 11 years after planting was considerably greater in the south Florida plantation than in the north Florida plantation (10.4 versus 0.5 conelets per tree) even though the trees in the former were on the average 8 feet shorter. Multi-whorl conelets were common in south Florida but not in the north. Significant differences in number of conelets occurred both among seed sources and families within seed sources. Tenth-year heights and 1973 conelet production in the south Florida plantation were significantly correlated ($r = 0.38$). Within plantings, taller trees generally produced more cones.

Additional keywords: Pinus elliottii Engelm., site effects, conelet production, racial variation.

Seed orchard managers are wondering why some of their orchards are producing heavy cone crops while others of the same age are not. Racial variation studies may provide a partial answer to this question. The objective of this study was to determine what effect planting site and seed source have on early cone production of slash pine (Pinus elliottii Engelm.).

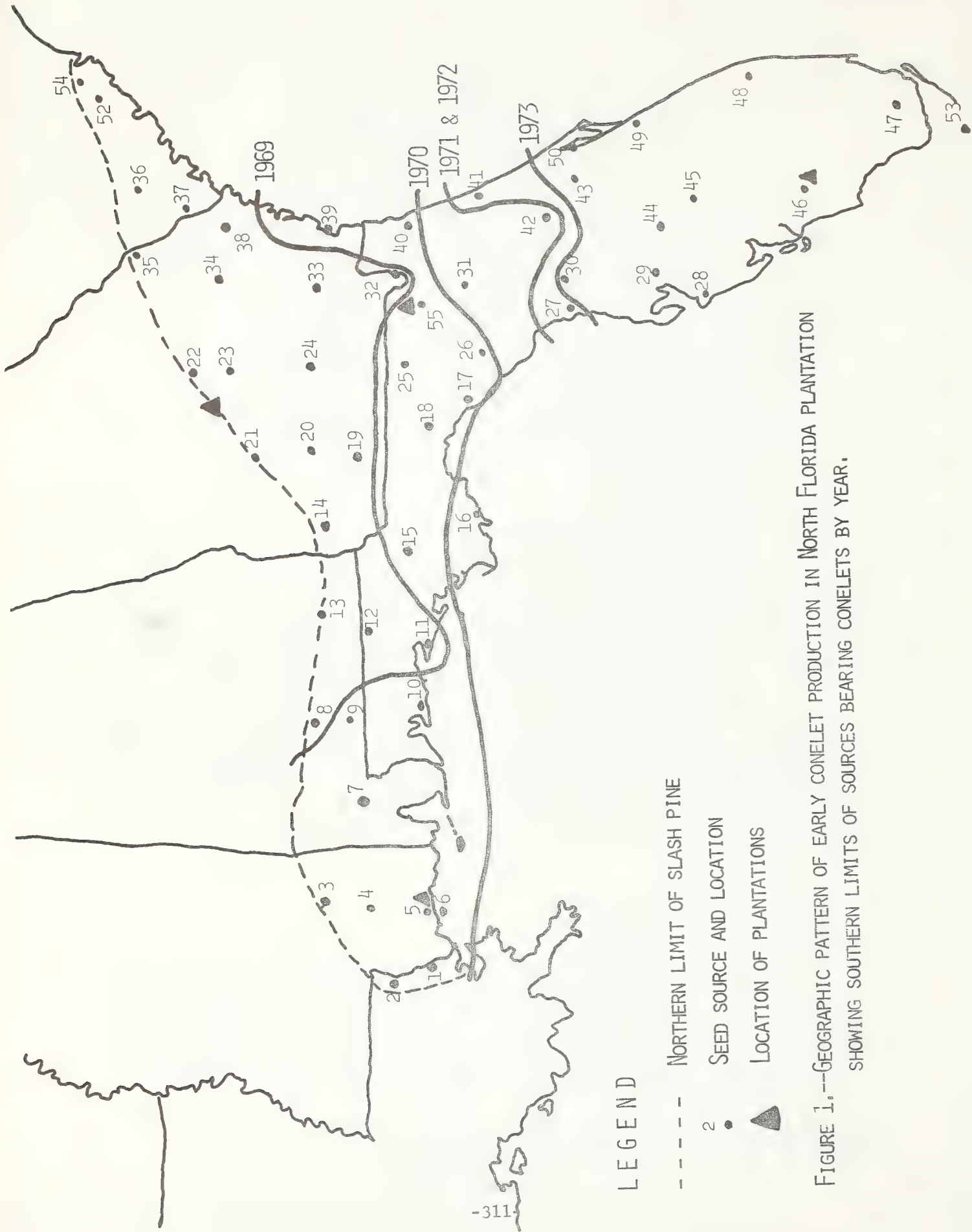
Information in the literature on this subject is very limited. Boyer and Evans (1967) reported that early flowering in longleaf pine (P. palustris Mill.) may be influenced by seed source. Wells and Wakeley (1970) found well-defined patterns of variation in degree of early cone production in shortleaf pine (P. echinata Mill.). The large seed source study of slash pine described by Squillace (1966) provided an excellent opportunity for studying the effects of planting site and seed source on early flowering.

PROCEDURE

Seed Sources and Planting Sites

Progeny from 53 slash pine seed sources are represented in the racial variation study (fig. 1). It samples the entire natural range of slash pine from Georgetown, South Carolina to the tip of the Florida peninsula and westward to New Orleans, Louisiana. At each source, seed were collected from 5 trees and kept separate by mother tree. Seedlings were grown at Olustee and established in four plantations in 1962. The plantations are located in Bleckley County, Georgia; Baker and Collier Counties, Florida; and Harrison

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County, Mississippi. A complete description of the study was presented by Squillace (1966). Information on early flowering reported here was obtained from the two Florida plantations.

Measurements and Analysis

Conelet counts were first made in the Baker County plantation in 1969, 7 years after outplanting when the trees first started flowering. Counts were made in the spring after the new shoots had elongated but before the new needles obscured the conelets. The conelets were highly visible at this time. Subsequent counts were made annually for 5 years. A total of 2,131 trees were observed in the Baker County plantation. Conelet counts were made in the Collier County plantation in the spring of 1972 and 1973. A total of 1,875 trees were observed in this plantation.

The data were analyzed using an analysis of variance for a hierarchical design with unequal numbers of trees per family and families per source (Snedecor 1956, p. 271). A correlation analysis using family means was used to determine if early cone production and height were correlated.

RESULTS

Genetic variation in early cone production in the 11-year-old slash pine seed source study was very evident. In the north Florida plantation, trees from the more northerly sources were the first to produce cones. As the trees grew older, more southerly sources started cone production (fig. 1). After 5 years, the most southerly source flowering was Citrus County. Average numbers of conelets per tree by source for the first 5 years of production are presented in Figure 2. The geographic pattern for conelet production was similar to that found for height growth (Gansel *et al.* 1971).

Conelet production in the south Florida plantation for 1972 and 1973 is presented in Figure 3. Geographic patterns are not the same as that found in the north Florida plantation. A coastal effect was evident, with production being generally lower for sources near the coast and increasing inland. Conelet production per tree by source and distance from the coast were correlated ($r = .50$). Even the more southerly sources are producing conelets at a younger age.

The average number of conelets produced by year for both plantations is presented in Table 1.

The 1973 conelet production and 10th year heights by family in Collier and Baker Counties were correlated ($r = .38$ and $r = .18$, respectively). Even though the correlation is not very strong, the taller trees generally produced the most cones. Double whorls of conelets were common in the south Florida plantation but absent in the Baker County plantation.

An analysis of variance was run on the Collier County plantation data and is presented in Table 2.

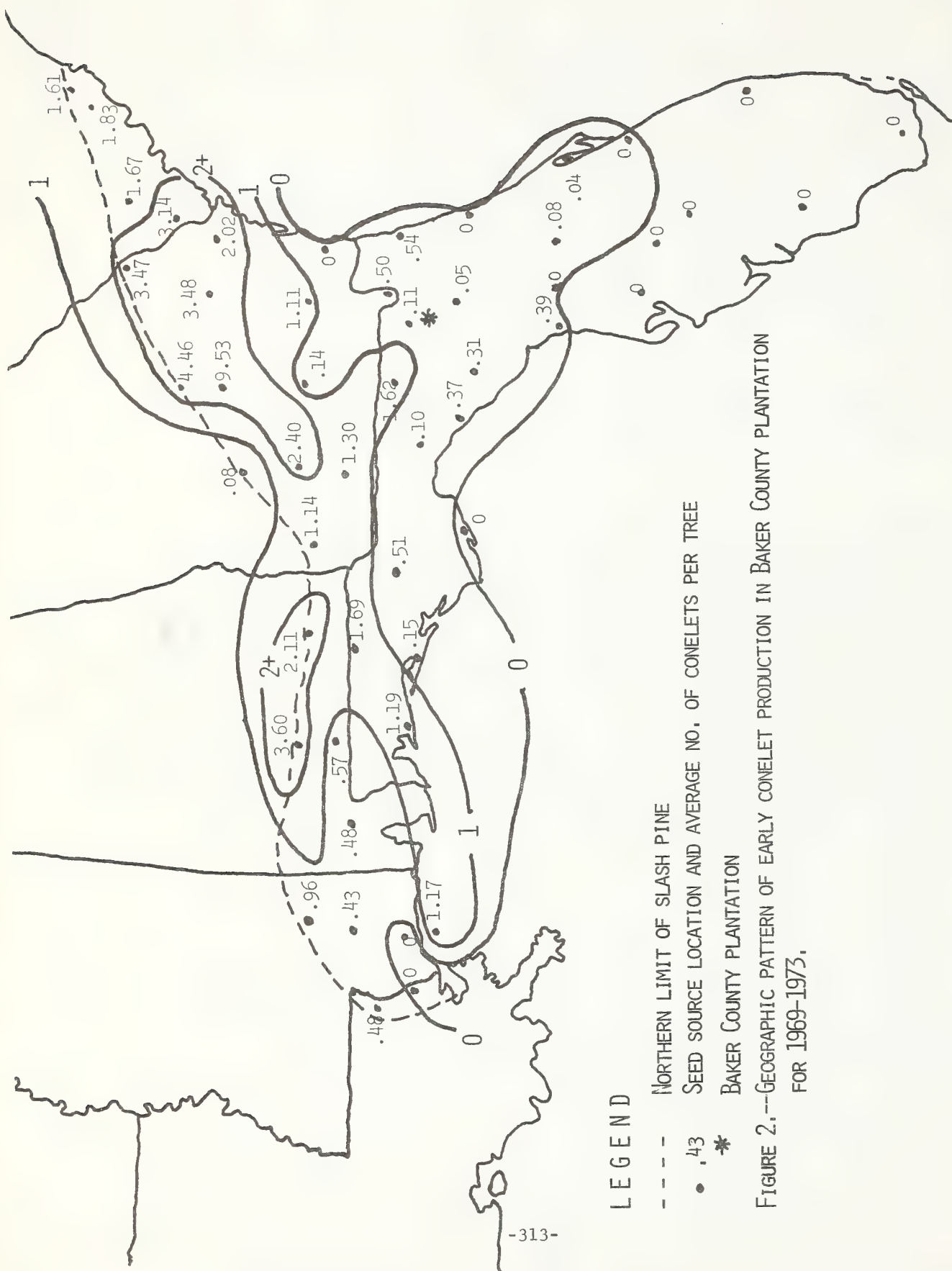


FIGURE 2. --GEOGRAPHIC PATTERN OF EARLY CONELET PRODUCTION IN BAKER COUNTY PLANTATION FOR 1969-1973.

Table 1.--Average conelet production per tree for the Florida plantations

Year	Baker County plantation	Collier County plantation
1969	0.03	not counted
1970	0.22	"
1971	0.08	"
1972	0.37	3.58
1973	0.47	10.38
Conelets per tree (number)		

Table 2.--Analysis of variance for conelet production in the Collier County plantation in 1973.

Source of variance	df	MS _a	Components
Seed source	49	585.76*	$\sigma^2_w + n_o A \sigma^2_m + (nb) \sigma^2_s$
Mother tree/source	171	393.90**	$\sigma^2_w + n_o B \sigma^2_m$
Trees/mother/source	1654	213.12	σ^2_w

a/ * Significant at 0.05 level
 ** Significant at 0.01 level

Seed sources were significantly different at the 0.05 level while family differences were significant at the 0.01 level. The component of variance due to family was 4 times greater than that for source.

In addition to the genetic effects, we also have a large site effect. The site effect is largely responsible for the much greater overall production of the south Florida plantation, which produced 10.4 versus 0.5 conelets per tree in 1973. The trees were approximately 30% shorter in the Collier County plantation (19 versus 27 feet) at the time of the 10th year measurements in 1972.

Application of Results

The first thing one may conclude from the results is that slash pine seedling seed orchards planted in the southern part of the species range will produce more conelets earlier on smaller trees than those planted in the

northern part of the range. However, before moving all our seed orchards south, remember that in this study conelets were counted, not mature cones full of seed. Also, we must remember that seedlings rather than grafts were used in this study. Orchards composed of vegetative propagules may or may not show the strong planting site effect reported here. A large percentage of conelets never develop into mature cones. There are numerous pitfalls in cone and seed development. Some pertinent questions to be considered are: How does seed set in the northern seed orchards compare with that in the south? What happens to flowering synchronization when trees are moved long distances to adverse sites? Is strobili receptivity still synchronized with pollen shedding? Will cone production in the northern plantation overtake production of the southern plantation in time? These questions should raise the caution sign.

What advantages are possible by moving seed orchards southward?

1. Potential for heavier and earlier cone production.
2. Elimination of damage from snow and ice storms.
3. Tender conelets and pollen less likely to be damaged by late hard frosts.
4. Reduced fusiform rust damage in the seed orchards.
5. Possibility of less outside pollen contamination in the orchard because flowering is not synchronized with the native population.

With all these potential advantages the possibility of moving seed orchards southward should not be overlooked.

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COMPARISON OF GENETIC PARAMETERS FOR WOOD PROPERTIES
EXPRESSED ON VOLUMETRIC AND GRAVIMETRIC BASES

E. C. Franklin^{1/}

Abstract.--Estimates of genetic parameters for wood properties and their interpretations can vary substantially depending on the units in which the wood properties are expressed. Of particular concern in this respect are estimates of genetic variances for moisture content, extractives yield and pulp yield when these traits are expressed on a gravimetric (dry weight) rather than volumetric basis. Corresponding estimates of genetic correlations of these variables with density depend strongly on the unit basis used. Arguments favoring the use of the volumetric basis for expression of certain wood properties are strengthened by comparing results of genetic analyses of traits expressed on the gravimetric versus volumetric bases.

Additional keywords: Density, moisture content, extractives yield, pulp yield, heritability, phenotypic correlations, genetic correlations.

Many studies have been conducted in recent years to achieve a clearer understanding of the relationships between wood density, moisture content, extractives yield and pulp yield. For reasons of tradition, ease of measurement, and consistency with industrial standards, most researchers have expressed moisture content, extractives yields and pulp yields on the gravimetric basis (i.e., per unit dry weight of wood) rather than the volumetric basis (i.e., per unit volume of wood). It has been recently shown that estimates of statistical correlations can be substantially biased if analyses are done between density and moisture content, extractives yield and pulp yield when the latter three variables are expressed on the gravimetric basis (Franklin and Squillace, In press). Similar biases are introduced into estimates of genetic parameters which are based on analyses of the relationships between density and other traits expressed on the gravimetric basis.

An introduction to the problem might be best accomplished by use of a contrived, though realistic example (table 1). Note that a wide array of densities has been listed in the first column. For purpose of illustration, moisture content and extractives yields were held constant on the volumetric basis and pulp yield was varied on the volumetric basis in direct proportion to density. This situation agrees closely with observed data. The key to understanding the problem lies in the simple mathematical conversion of volumetric to gravimetric bases, which is accomplished by dividing the volumetric array by density and multiplying by 100.

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Table 1.--A contrived example for comparisons of unit volume and unit dry weight expressions of moisture content, extractives yield, and pulp yield.a/

<u>Density</u>		<u>Moisture content</u>		<u>Extractives yield</u>		<u>Pulp yield</u>	
$\frac{W}{V}$		$\frac{M}{V}$	$\frac{M}{W} \times 100$	$\frac{E}{V}$	$\frac{E}{W} \times 100$	$\frac{P}{V}$	$\frac{P}{W} \times 100$
(g/cc)		(g/cc)	(g/g)	(g/cc)	(g/g)	(g/cc)	(g/g)
.16		.45	281	.014	8.8	.08	50
.24		.45	188	.014	5.8	.12	50
.32		.45	141	.014	4.4	.16	50
.40		.45	112	.014	3.5	.20	50
.48		.45	94	.014	2.9	.24	50
.56		.45	80	.014	2.5	.28	50
.64		.45	70	.014	2.2	.32	50
.72		.45	62	.014	1.9	.36	50

a/
W = weight of wood substance (cellulose, lignin, sugars, etc.)
M = weight of moisture
E = weight of extractives
P = weight of pulp
V = volume of sample of green wood

Using the symbols in Table 1, the formula for converting moisture content on the volumetric basis to the gravimetric basis is as follows:

$$\begin{aligned}
 \frac{M}{W} \times 100 &= \frac{M}{V} \div \frac{W}{V} \times 100 \\
 &= \frac{M}{V} \times \frac{V}{W} \times 100 \\
 &= \frac{M}{W} \times 100
 \end{aligned}$$

Two important facts should be noted in comparing the volumetric and gravimetric arrays in Table 1. First, gravimetric arrays for moisture content and extractives yields are non-linear with respect to density (i.e., unit changes in the volumetric arrays do not correspond with unit changes in the gravimetric arrays). Second, constancy on one basis is accompanied by large amounts of variation on the other basis and the variation depends directly on density.

The conclusion to be drawn from Table 1 is that correlations based on relationships between density and the other three variables will be quite different depending on which basis of expression is used. The question then is, "Which basis accurately reflects the biological relationships which are being studied?" The answer is the volumetric basis because the gravimetric basis has a negative correlation with density because it is derived from the volumetric basis by dividing by density. The correlation between a variable

and its reciprocal is non-linear and negative; therefore, the relationships between density and the other three variables on the gravimetric basis is a combination of the induced reciprocal relationships plus any biological relationship which may also exist. This can be shown very neatly by a mathematical analysis of the expected correlation coefficients.^{2/}

Estimates of genetic parameters for wood properties and their interpretation can vary substantially depending on the basis of expression, (volumetric or gravimetric). This will be illustrated by an example based on data from slash pine (Pinus elliottii Engelm.) and one based on data previously published by van Buijtenen et al. (1968) from loblolly pine (P. taeda L.).

The slash pine study consisted of single-tree plots from 31 nominal half-sib families replicated 5 times. Measurements of green weight, dry weight of ethanol-benzene extractives were obtained by standard laboratory procedures. Estimates of density, moisture content and extractives yields were then obtained. Moisture content and extractives yield were expressed both on volumetric and gravimetric bases. Components of phenotypic and genotypic variances were derived by analysis of variance procedures. The coefficient of relationship for siblings was assumed to be 1/3 rather than 1/4; therefore, a multiplier of 3 rather than 4 was appropriate.^{3/}

The loblolly study has been described in detail previously (van Buijtenen et al. 1968). It consisted of 4 ramets from each of 6 clones. The same measurements as those in the slash pine study were obtained in addition to pulp yield. Density, yield of ethanol-benzene extractives, and pulp yield were analyzed by analysis of variance to derive phenotypic and genotypic variance components.

Values in Tables 2 and 3 indicate that both the direction and magnitude of changes in heritability estimates are rather erratic. Heritability estimates for moisture content and extractives yield are higher on the gravimetric than on the volumetric bases. This is because the heritability for density is usually higher than that for moisture content or extractives yield, thus dividing by density increases the heritability estimate for the gravimetric basis by increasing the family intraclass correlation. In the case of a trait such as pulp yield (table 3) where the heritability on the volumetric basis is approximately equal to that of density, the change in the estimate of heritability for pulp yield on the gravimetric basis becomes much less predictable.

The situation with reference to phenotypic and genotypic correlations was much more consistent. In every case, correlation estimates based on the gravimetric basis were consistently larger negative values or smaller positive values than comparable estimates based on the volumetric basis. Differences in all cases were large enough to lead to serious errors of interpretation unless the researcher realized that the differences were simply the result of an algebraic manipulation. This does not mean that the gravimetric basis has

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^{3/} Personal communication from Dr. A. E. Squillace, Southeast. For. Exp. Stn., P. O. Box 70, Olustee, Florida, 32072.

Table 2.--Heritabilities, phenotypic and genetic correlations for three wood properties estimated by sibling intraclass correlations with 31 families of slash pine (*Pinus elliottii* Engelm.) and expressed on gravimetric versus volumetric bases.

	<u>Gravimetric basis</u>	<u>Volumetric basis</u>
HERITABILITIES ^{a/}		
Density of Extracted Wood	---	0.59
Moisture Content of Green Wood	.26	.22
Extractives Yield of Wood	.48	.41
PHENOTYPIC CORRELATIONS		
Density with Moisture Content	-0.33	- .08
Density with Extractives Yield	-0.35	.00
GENETIC CORRELATIONS ^{a/}		
Density with Moisture Content	- .37	+ .27
Density with Extractives Yield	- .49	- .13

^{a/} Narrow-sense heritabilities and genetic correlations (Hanson 1963)

Table 3.--Heritabilities, phenotypic and genotypic correlations for three wood properties estimated by ramet intraclass correlations with 6 clones of loblolly pine (*Pinus taeda* L.) and expressed on gravimetric versus volumetric bases (portions of original data from van Buijtenen et al. 1968).

	<u>Gravimetric basis</u>	<u>Volumetric basis</u>
HERITABILITIES ^{a/}		
Density of Extracted Wood	---	0.88
Extractives Yield of Wood	0.66	0.51
Pulp Yield	.52	.85
PHENOTYPIC CORRELATIONS		
Density with Extractives Yield	- .34	0.16
Density with Pulp Yield	.43	.98
GENETIC CORRELATIONS ^{a/}		
Density with Extractives Yield	-0.50	0.04
Density with Pulp Yield	0.57	0.97

^{a/} Broad-sense heritabilities and genetic correlations (Hanson 1963)

no valid uses; it does mean that the volumetric basis is better than the gravimetric basis for expression of wood properties if those properties are to be compared with density, and those comparisons used for estimation of genetic parameters.

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SELECTION INDICES FOR WOOD QUALITY
IN LOBLOLLY PINE

M. D. Wilcox and H. D. Smith^{1/}

Abstract.--Classical Smith-Hazel linear selection indices were developed to aid in selecting groups of loblolly pine clones with desired combinations of wood characteristics. Mean specific gravity is increased and mean lignin content decreased in an index designed to identify clones with improved kraft pulping properties. Another index, for improving the yield and brightness of mechanical pulps, identifies clones which combine high specific gravity and high brightness. Improvement in the strength and brightness of mechanical pulps is the objective of the third index, favoring clones combining low specific gravity and high brightness. No matter what combination of characteristics is desired, aggregate expected gains from index selection are always greater than from single trait selection.

Within-clone variances for specific gravity, lignin content and brightness are highly heterogeneous. A further index is described which chooses clones such that the total variability (among clones and within clones) of a wood property is minimized. Much better wood uniformity can be achieved by this method than by selecting on means alone.

For multiple trait selection, the two kinds of indices can, in effect, be combined, resulting in an index that not only changes the mean of each wood property in the desired direction but also increases the uniformity of the wood as a raw material for pulping.

Additional keywords: Pinus taeda, clonal selection, selection indices, wood brightness, specific gravity, lignin content, specific light absorption coefficient, improved wood uniformity, improved pulping properties.

^{1/}Graduate students, School of Forest Resources, North Carolina State University, Raleigh, N. C. 27607. (Dr. B. J. Zobel is thanked for making the clones available for this study and for his help with the paper.)

INTRODUCTION

Multiple trait selection is most efficiently handled by some form of selection index which gives optimum weight to each trait. Empirical selection indices have been embodied in numerous tree scoring or grading methods for selecting superior trees (van Buijtenen, 1969). A disadvantage of these arbitrary point systems is that they do not always recognize and properly take into account the genetic characteristics and economic importance of the traits involved, and thus have no optimum properties--in fact, no properties at all other than that they seem "reasonable." Analytical indices derived from measures of variability and covariability and economic importance of traits have the advantage of optimizing the aggregate gain in a number of traits, thus allowing maximum economic returns from the tree breeding program.

The purpose of this paper is to describe the development and application of two kinds of selection indices in clonal selection: one for optimizing the aggregate gain in several wood properties, the other for minimizing the variability of the wood properties. Further, it will be shown that the two types of indices may be combined to select groups of clones having all-round better and more uniform properties. When the proper economic weights are assigned to each trait, and to unit reductions in variability versus unit increases in the means, these selection methods should optimize the economic gain per unit volume of wood from clonal selection.

SMITH-HAZEL LINEAR SELECTION INDICES

Theory

Information pertaining to n traits can be combined in a linear clonal selection index of the form

$$I_i = \sum_j^n b_j P_j \quad (\text{Equation 1})$$

where P_j is the measured value of the j^{th} trait for the i^{th} clone, and I_i is the i^{th} index value for the i^{th} clone. For two traits, as in the examples to be described,

$$I_i = b_1 P_{i1} + b_2 P_{i2} \quad (\text{Equation 2})$$

The b_j 's are least squares solutions to a set of equations and are estimated from

$$\hat{\underline{b}} = \underline{P}^{-1} \underline{A} \underline{S}^{-1} \underline{a} \quad (\text{Equation 3})$$

where \underline{P} is the phenotypic variance-covariance matrix, \underline{A} is the clonal variance-covariance matrix, \underline{S} is a diagonal matrix of the phenotypic standard deviations, and \underline{a} is a vector of economic weights. The \underline{S} matrix is included to weight the economic values by the inverse of the phenotypic standard deviations, freeing the index values of scaling effects due to different units of measurement. If phenotypic and clonal covariances are zero, the matrix $\underline{P}^{-1}\underline{A}$ simplifies to a diagonal matrix, \underline{H} , of the clonal repeatabilities.

The index coefficients (b_i 's) define an optimum index theoretically allowing maximum aggregate gain for the n traits. This is a unique property of the classical Smith-Hazel index. As pointed out by Namkoong (1969), in practice there are two serious problems limiting the usefulness of this kind of selection index. One is that the economic value functions of many traits are unlikely to be linear. The other is that poorly estimated index coefficients, resulting from poorly estimated variance-covariance matrices, are far from optimum and may result in selection indices that do no better (or may even do worse) than arbitrary "common-sense" point systems.

Indices to select clones with improved pulping qualities

Indices were derived from variances and covariances estimated in a study of variation in wood brightness and specific gravity in 37 grafted clones of loblolly pine (*Pinus taeda* L.). The three traits considered were specific gravity, wood brightness and specific light absorption coefficient, which is a good indirect measure of lignin content (Wilcox, 1973).

Index 1 is designed to select clones with improved kraft pulping properties by favoring those which combine high specific gravity and low absorption coefficient (= low lignin content). High juvenile wood specific gravity is the breeding objective emphasized for this trait because of the need to increase the generally poor pulp yields from young wood (Kirk, et al., 1972). Expected benefits are increases in pulp yield per unit volume and per unit dry weight of wood, increases in tear strength (Barefoot, et al., 1970), and possibly reductions in cooking times and chemical consumption in pulping to a given Kappa number.

Index 2 is designed to select clones with a high specific gravity and high brightness. This combination of characteristics is expected to reduce the cost of production of stone-groundwood and refiner mechanical pulp by increasing the yield of pulp per unit volume of wood, by reducing the energy requirement per ton of pulp produced, and by increasing the production rate per stone or per refiner day (Bryant, 1970). Brightness increases may be sufficient to eliminate the need for or reduce the cost of chemical brightening, and to improve the bleachability of high-yield pulps to high brightnesses (Wilcox, 1973).

Index 3 selects clones with improved high-yield pulp (e. g., chemi-groundwood, disk refiner mechanical pulp) qualities by favoring clones combining high brightness and low specific gravity. Pulps from clones having wood with these characteristics will have improved brightness and superior fiber-to-fiber bonding (Smith and Byrd, 1972), giving papers with good printing qualities (improved smoothness, brightness, and perhaps scattering coefficient and opacity) as well as improved burst and tensile strengths. The index could also be used to select clones with improved qualities for the manufacture of printing papers and tissue papers from pine kraft pulp (Fahey, et al., 1968).

The indices are:

Index 1 = $(36.043 \times \text{specific gravity}) - (.1543 \times \text{absorption coefficient})$

Index 2 = $(32.786 \times \text{specific gravity}) + (.464 \times \text{brightness})$

Index 3 = $(-36.598 \times \text{specific gravity}) + (.4223 \times \text{brightness})$

Gains from index selection

In the analyses made here, specific gravity, brightness and absorption coefficient were assigned equal economic weights. This means that equal economic values have been attached to changes of one standard deviation in specific gravity (0.023), brightness (1.36 points) and absorption coefficient ($-4.7 \text{ cm}^2/\text{g}$ --equivalent to a reduction of 0.5% in Klason lignin content of wood). Different selection procedures can therefore be evaluated from comparisons of aggregate realized gains expressed in standard deviation units (Table 1).

Index 1, favoring high specific gravity and low absorption coefficient, gives worthwhile improvement in both wood properties (Table 1). There is effectively no linear correlation between the two traits--in fact, both low and high specific gravities may be associated with high absorption coefficients. Selection solely for low absorption coefficient does not change the specific gravity, and maximum gain in absorption coefficient can be made without an effect on specific gravity. Gains from Index 1 were an increase of 0.027 in specific gravity and a reduction in absorption coefficient of $4.5 \text{ cm}^2/\text{g}$, this latter being approximately equivalent to a reduction in lignin content of 0.5%, from 28.95% to 28.45% (Wilcox, 1973).

The negative correlation between specific gravity and brightness makes it difficult to select clones combining both high specific gravity and high brightness. Selection for either characteristic alone results in a loss in the other. However, selection Index 2 more than doubles the aggregate gain possible from single trait selection (Table 1), showing that it is effective in working against and breaking the unfavorable specific gravity-brightness correlation. Index 1 and Index 2 both select the same group of clones since high brightness is associated with low absorption coefficient.

The negative correlation between specific gravity and brightness is highly advantageous when clones combining low specific gravity and high brightness are desired (Index 3). Selection for either characteristic alone guarantees some improvement in the other; but even here, index selection is worthwhile, resulting in 13% more aggregate gain than from single trait selection (Tables 1 and 2). However, the advantage of this kind of selection index over other methods of multiple trait selection is greatest when the characteristics desired tend to be unfavorably correlated.

If improvement in wood brightness is to be the major thrust in a breeding program for loblolly pine, the realized gain from selecting the best 3 clones out of 37 solely for brightness is 2.3 points, based on the data from 12-year-old grafts (Wilcox, 1973). The best alternative is Index 3 (Table 2) with a gain of 1.9 points. Selection only for low specific gravity produces a correlated gain in brightness of 1.0 point. A gain of one point in wood brightness translates into a saving in groundwood bleaching cost of approximately \$1 per ton of pulp, or \$1 per cord of pulpwood processed. Put another way, a one point gain in wood brightness represents about a \$40-per acre saving to the mill.

Table 1.--Effectiveness of alternative methods of selecting
3 best loblolly pine clones from a total of 37 clones

A. Combining high specific gravity and low lignin content

Selection method	Clones selected	Aggregate gain ^{a/}
Select only for high specific gravity	8-61, 8-49, 8-26	1.101
Select only for low absorption coefficient	8-24, 8-107, 8-83	1.568
Selection Index 1	8-24, 8-49, 8-67	2.137 (36%)

B. Combining high specific gravity and high brightness

Selection method	Clones selected	Aggregate gain
Select only for high specific gravity	8-61, 8-49, 8-26	0.525
Select only for high brightness	8-27, 8-107, 8-44	0.765
Selection Index 2	8-49, 8-67, 8-24	1.632 (113%)

C. Combining low specific gravity and high brightness

Selection method	Clones selected	Aggregate gain
Select only for low specific gravity	8-126, 1-9, 8-27	2.434
Select only for high brightness	8-27, 8-107, 8-44	2.575
Selection Index 3	8-126, 8-27, 8-107	2.968 (13%)

^{a/} Standard deviations. (%) is superiority of index over next best method.

Table 2.--Use of Index 3 to select clones giving maximum aggregate gain
in brightness and specific gravity^{a/}

Clone ^{b/}	Rank			Mean		
	Index 3 ^{c/}	SG	Brightness	Index	SG	Brightness (%)
8-126	1	1	13	9.9930	.305	50.11
8-27	2	3	1	9.9869	.329	52.18
8-107	3	4	2	9.7643	.333	52.03
1-77	4	10	5	8.9558	.342	50.84
1-9	5	2	23	8.9539	.322	49.16
8-44	6	14	3	8.8133	.349	51.14
1-60	7	7	15	8.7465	.338	50.03
8-46	8	9	16	8.6598	.340	49.98
8-73	9	5	19	8.5723	.337	49.54
8-134	10	15	9	8.4331	.351	50.44
8-114	11	21	4	8.3776	.359	50.93
8-128	12	18	11	8.3447	.353	50.38
8-50	13	16	14	8.2416	.352	50.05
8-129	14	6	26	8.2299	.337	48.73
8-120	15	8	25	8.2209	.340	48.92
4-19	16	13	21	8.1743	.347	49.41
8-130	17	22	10	8.1439	.359	50.44
8-144	18	12	24	8.0590	.347	49.13
1-25	19	20	17	7.9758	.358	49.92
1-23	20	17	20	7.9534	.353	49.45
8-123	21	27	8	7.8632	.367	50.46
8-37	22	11	31	7.7956	.345	48.37
8-13	23	24	18	7.7662	.364	49.92
8-83	24	30	12	7.5775	.373	50.28
8-67	25	32	6	7.5413	.378	50.65
8-24	26	31	7	7.4872	.378	50.49
8-29	27	19	30	7.4617	.357	48.62
1-68	28	25	29	7.2324	.364	48.65
8-10	29	26	28	7.1845	.365	48.67
8-7	30	23	32	7.1029	.362	48.21
8-5	31	29	27	6.9122	.373	48.68
8-49	32	36	22	6.2560	.398	49.33
8-80	33	34	33	5.8335	.394	47.98
1-16	34	33	36	5.3692	.386	46.19
1-22	35	28	37	5.3187	.370	44.66
8-26	36	35	35	5.2977	.394	46.68
8-61	37	37	34	4.8289	.412	47.14

^{a/} Low specific gravity and high brightness are the desired wood characteristics in this example.

^{b/} Clones with the prefix 1- belong to Hiwassee Land Company (Bowaters Southern Paper Corporation), the clone with prefix 4- to Chesapeake Corporation, and the clones with 8- to Weyerhaeuser Company.

^{c/} Index 3 = (-36.598 x specific gravity) + (.4223 x brightness).

An empirical index for maximizing aggregate selection differentials

In the indices previously discussed, clonal and phenotypic covariances were small, clonal repeatabilities were approximately equal, and economic weights of the traits were assumed to be equal. Under these special circumstances, a simple method of approximating the expected Smith-Hazel index rankings is to compute and rank the actual aggregate selection differentials in standard deviations for each clone. Indices of this form are:

$$I_i = \sum_j^m \frac{c_i(j)}{\frac{1}{a_j} \sigma_{p_j}} \quad (\text{Equation 4})$$

where I_i is the aggregate selection differential in standard deviations from selecting the i^{th} clone based on its performance for m traits; $c_i(j)$ is the effect (*i. e.*, $\mu - \hat{\mu}_i$) of the i^{th} clone for the j^{th} trait; a_j is the economic weight of the j^{th} trait; and σ_{p_j} is the phenotypic standard deviation of the j^{th} trait.

The I 's for each clone can therefore be calculated from the clone means, the grand means of all the clones, and the phenotypic standard deviations appropriate to the proposed method of selection. Selection involves only ranking the I 's and picking the winners.

An example of this kind of selection index, using the data from the wood brightness study (Wilcox, 1973) is

$$\text{Index 4} = [(SG-.358)/.0232] + [(15.9-SUMM)/4.212] + [(52.956-ABSORP)/4.6656] + [(BRIGHT -49.52)/1.3565] + [(3.438-COMPR)/2.211]$$

Characteristics favored are high specific gravity, low summerwood percent, low absorption coefficient (= low lignin content), high brightness and low percent compression wood. All characteristics have been assigned the same economic weight. Clone 8-67, a loblolly pine from the Coastal Plain of North Carolina, has an unusually favorable combination of characteristics and a high index value (Table 3). It is exceptional in that it has a combination of the lowest summerwood percent of all clones, with the sixth highest specific gravity.

Equation 4 (see above) can be used to compute the approximate expected Smith-Hazel index rankings, against which the rankings based on the corresponding analytical indices can be compared. Very good agreement between expected (*i. e.*, the actual aggregate clone values) rankings and those from the analytical indices were obtained. Ranks for the best 10 clones for each of three combinations of desired characteristics are shown in Table 4. The analytical indices clearly come very close to giving the the expected maximum aggregate gain, showing that the index coefficients are reasonable estimates of the parameters. At the same time, the good agreement between observed and expected ranks (Table 4) indicates that simple empirical indices based on Equation 4 are generally useful for ranking clones when no information is available on the heritabilities and correlations of the traits in question.

Table 3.--Use of Index 4 to identify clones having an optimum combination of wood quality characteristics

Clone ^{a/}	Index 4 ^{b/}	Rank					
		INDEX	SG	SUMM	ABSORP	BRIGHT	COMPR
8-67	4.7112	1	6	1	7	6	8
8-107	4.4669	2	34	5	2	2	2
8-83	4.1313	3	8	12	3	12	3
8-27	3.4515	4	35	4	8	1	6
8-134	3.3892	5	23	11	4	9	1
8-130	3.0453	6	16	15	9	10	5
8-123	2.7213	7	11	14	5	8	18
8-24	2.4614	8	7	32	1	7	20
8-44	1.6358	9	24	19	17	3	12
8-13	1.6344	10	14	25	14	18	11
8-50	1.5030	11	22	28	10	14	7
8-128	1.0437	12	20	26	13	11	16
8-114	0.8812	13	17	35	6	4	19
8-5	0.8663	14	9	30	11	27	10
1-68	0.6654	15	13	13	19	29	9
8-25	0.4095	16	18	6	26	17	22
8-46	0.1237	17	29	21	12	16	23
8-10	0.0965	18	12	29	23	28	4
8-49	-0.1721	19	2	36	16	22	28
1-60	-0.2372	20	31	2	31	15	21
1-23	-0.6550	21	21	18	18	20	29
8-120	-0.7727	22	30	10	21	25	17
8-37	-0.8143	23	27	8	29	31	13
8-29	-0.9373	24	19	16	32	30	15
4-19	-0.9844	25	25	9	25	21	27
8-144	-1.1475	26	26	20	20	24	25
1-77	-1.3137	27	28	24	15	5	36
8-129	-1.5454	28	32	7	27	26	24
8-80	-1.8230	29	4	37	22	33	26
8-126	-2.0677	30	37	23	28	13	14
8-61	-2.1793	31	1	22	35	34	32
8-73	-2.2248	32	33	3	30	19	35
8-7	-3.0280	33	15	34	24	32	30
1-9	-3.6750	34	36	17	33	23	31
8-26	-3.8883	35	3	31	34	35	33
1-16	-4.8966	36	5	28	36	36	34
1-22	-11.4537	37	10	33	37	37	37

^{a/} Clones with the prefix 1- belong to Hiwassee Land Company (Bowaters Southern Paper Corporation), the clone with prefix 4- to Chesapeake Corporation, and the clones with 8- to Weyerhaeuser Company.

^{b/} Aggregate selection differential in standard deviations

Table 4.--Comparison of rankings for clones which actually give maximum aggregate selection differentials with rankings derived from Smith-Hazel analytical selection indices^{a/}

Clone	Actual Rank	Index 1 Rank	Clone	Actual Rank	Index 2 Rank	Clone	Actual Rank	Index 3 Rank
8-24	1	1	8-67	1	2	8-27	1	2
8-49	2	2	8-49	2	1	8-107	2	3
8-83	3	4	8-24	3	3	8-126	3	1
8-67	4	3	8-83	4	4	1-77	4	4
8-123	5	5	8-123	5	5	8-44	5	6
8-5	6	7	8-114	6	6	1-9	6	5
8-80	7	6	8-44	7	10	1-60	7	7
8-114	8	9	8-107	8	12	8-46	8	8
8-13	9	10	8-130	9	9	8-114	9	11
8-130	10	11	8-27	10	13	8-134	10	10

a/ High specific gravity--low absorption coefficient

Actual aggregate

selection differential = $[(SG-.358)/.0232] + [(52.956 - ABSORP)/4.6656]$

Index 1 = $(36.043 \times SG) - (.1543 \times ABSORP)$

High specific gravity--high brightness

Actual aggregate

selection differential = $[(SG -.358)/.0232] + [(BRIGHTNESS -49.52)/1.3565]$

Index 2 = $(32.786 \times SG) + (.464 \times ABSORP)$

Low specific gravity--high brightness

Actual aggregate

selection differential = $[(.358 - SG)/.0232] + [(BRIGHTNESS - 49.52)/1.3565]$

Index 3 = $(-36.598 \times SG) + (.4223 \times BRIGHTNESS)$

UNIFORMITY INDICES

Variation in uniformity

Heterogeneous within-treatment variances are usually regarded in the context of their role in violating the assumptions underlying the analysis of variance. Thus, rather than accept the fact that some treatments are inherently more uniform than others, experimenters frequently attempt one or more mathematical transformations in an attempt to rescale the data and homogenize the variances. When the objective of an experiment is to rank and compare treatment means, there is naturally some reluctance to loudly advertise the existence of heterogeneous variances since this will cast doubt upon the validity of the numbers in the ANOVA table and on the significance of treatment differences.

The objective in assessing a clonal or progeny test is selection--not to do an analysis of variance. Since variances are as much a property of individual families or clones as are means, their separate calculation and recognition as important family traits are essential to determining the best families. Clonal variation in the uniformity of lignin content in loblolly pine wood is illustrated in Figure 1. Although the means of the two clones are the same, the variances are not, and clone 8-134 is preferred to clone 8-123 because of its greater uniformity.

An F-test is the usual way of establishing whether or not there are important differences among family means. The best known and most powerful of the many available tests that could be used to demonstrate variation among family variances is Bartlett's test (Gartside, 1972).

In our examples, clonal variances comprise two components: within-ramet, and among ramets at one site. The within-ramet variance contributed over 90% of the within-clone variation in wood characters. Within-clone variance can be regarded as a measure of the phenotypic plasticity (as opposed to genotypic stability) of a character (Bradshaw, 1965; Hanson, 1970). A uniform or stable clone produces similar wood year after year, regardless of varying annual environments; in a given season it also produces similar wood in different parts of the bole. Such morphological homeostasis is a desirable clonal characteristic and could be an important selection criterion for certain wood characters such as specific gravity. Another reason for recognizing clonal differences in wood uniformity is that clones with the smallest variances also have the most precise means and therefore the most predictable performances.

Application

Pulp manufacturers usually express a desire for more uniform wood. Reduced variability may be just as economically important as changes in the mean for certain wood properties such as lignin content and latewood percent. In kraft pulping, wide variation in lignin content (see Figure 1) of the raw material results in inefficient pulping: some of the wood is undercooked and some overcooked. Under given cooking conditions, variation in wood lignin content results in variation in pulp Kappa number. Thus, it becomes difficult to produce high-yield or "hard" pulp since that proportion of the wood with the highest lignin content will be undercooked, resulting in shives. Likewise the bleachability of "soft" or low Kappa kraft pulps will be reduced because some of the wood will have been cooked to a higher Kappa number than desired. Variation in latewood percent and specific gravity may have similar detrimental effects due to the variability in the accessibility of the pulping chemicals to the lignin. Therefore, improved wood uniformity will increase pulp yields, reduce pulping costs, and improve the uniformity of the product, thus improving economic returns.

Theory

In the application of the concept of variation in phenotypic uniformity to clonal selection it must be recognized that the total variability of a wood trait stems from two sources: variation among the clones in the select group, and the average within-clone variation. Equal importance is attached to both sources of variation in the following index procedure proposed as an aid to selection for uniformity.

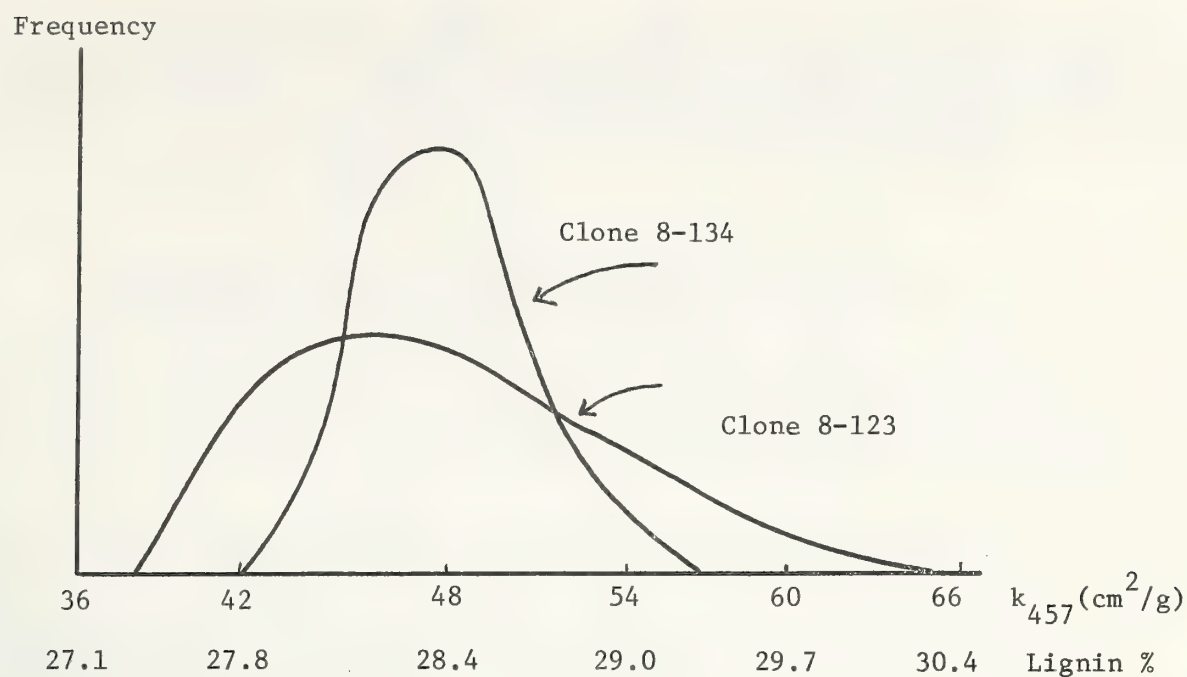


Figure 1.--Variation in the uniformity of lignin content in two loblolly pine clones (12-year-old grafts)a/

a/ Statistics of the two clones

A. Absorption coefficient (cm^2/g)

<u>Clone</u>	<u>Mean</u>	<u>Variance</u>	<u>Range</u>
8-134	47.7	13.0	43.3 - 55.2
8-123	47.8	63.9	37.7 - 66.2

B. Lignin content (% of wood dry weight)

<u>Clone</u>	<u>Mean</u>	<u>Range</u>
8-134	28.4	27.9 - 29.2
8-123	28.4	27.3 - 30.4

The objective is to select a group of n clones such that the total variability of a given trait is minimized. Individual clone means ($\hat{\mu}_i$) and within-clone variances ($\hat{\sigma}_{wi}^2$) must first be estimated. The uniformity index, J , of a select group of n clones from the array is the quantity to be minimized. It is the total variance,

$$J = \sigma_A^2 + \sigma_W^2 \quad (\text{Equation 5})$$

where σ_A^2 = the among-clone variance of the select group

$$\begin{aligned} &= \frac{\sum_i^n (\hat{\mu} - \hat{\mu}_i)^2}{n - 1} \\ &= \frac{\sum_i^n c_i^2}{n - 1} \end{aligned} \quad (\text{Equation 6})$$

and σ_W^2 = the average with-clone variance of the select group

$$\begin{aligned} &= \frac{\sum_i^n \hat{\sigma}_{wi}^2}{n} \end{aligned} \quad (\text{Equation 7})$$

$$\text{with } df_W = \sum_i^n df_i$$

$\hat{\mu}_i$ = the mean of the i^{th} clone, c_i = the effect of the i^{th} clone ($i = 1, 2, \dots, N$), $\hat{\sigma}_{wi}^2$ = variance of the i^{th} clone, $\hat{\mu}$ = the mean of the select group]

Since J is the sum of two mean squares, i. e.,

$$J = \text{MSA} + \text{MSW},$$

its degrees of freedom can be calculated using Satterthwaite's procedure:

$$df(J) = \frac{[\text{MSA} + \text{MSW}]^2}{\left[\frac{\text{MSA}^2}{df_A} + \frac{\text{MSW}^2}{df_W} \right]} \quad (\text{Equation 8})$$

A computer program (see Appendix) was written to compute and rank J for all possible groups of n clones from an array of N clones. In our examples, $n=3$ and $N=37$ or 10 , with $df(J)$ averaging 60 . The total number of combinations of size n from an array of size N is

$$C = \frac{N(N-1)\dots(N-n+1)}{n!} \quad (\text{Equation 9})$$

For example, for groups of size 3 from an array of 37 clones, there are

$$C = \frac{37 \times 36 \times 35}{6} = 7770 \text{ combinations.}$$

To test whether one clone group is more variable than another, an F statistic can be calculated from the ratio of the larger J over the smaller J and compared to $F_{1-\alpha}$. In addition, the ranked variances can be ordered into distinct groups using a multiple range test based on the maximum F-ratio test (Tietjen and Beckman, 1972).

Examples

(1) Unrestricted uniformity index--absorption coefficient

In this example the sole objective is to minimize J, the variability of absorption coefficient, as a measure of wood lignin content; no account is taken of average performance. Any gain in the mean will therefore result only from a favorable correlation between absorption coefficient means and variances.

From the array of 37 clones the group of 3 having the minimum J was

<u>Clone</u>	: 8-107	8-134	8-83
<u>Variance</u> :	14-65	13.01	24.80
<u>Mean</u> :	46.12	47.66	47.43

Index J = 18.1761

Group mean, absorption coefficient = $47.07 \text{ cm}^2/\text{g}$

Group mean, lignin content = 28.31%

Range of J for all 7770 combinations of 3 clones
= 18.1761 to 516.4746 (this represents a 28-fold
difference in wood uniformity between the most
uniform and least uniform groups).

The above group of clones is significantly more uniform than the group (8-24, 8-107, 8-83) selected only to maximize mean performance ($F = 3.027^{**}$).

(2) Unrestricted uniformity index--specific gravity

With the objective of again only minimizing J, the most uniform group of clones is

<u>Clone</u> :	8-134	8-128	8-44
<u>Variance</u> :	.000194	.000171	.000267
<u>Mean</u> :	.351	.353	.349

Index J = .000215

Group mean = .351

Range of J for all 7770 combination of 3 clones
= .000215 to .018798 (this represents an 87-fold
difference in wood uniformity between the most
uniform and least uniform groups).

The above group of clones is significantly more uniform than the group (8-61, 8-49, 8-26) with the highest mean specific gravity ($F = 20.379^{**}$), or the group (8-126, 1-9, 8-27) with the lowest specific gravity ($F = 2.338^{**}$).

If there is doubt as to whether high or low specific gravity is the desired pulpwood characteristic, then a strategy which will always result in some improvement in wood quality is to select only to maximize uniformity. Especially for wood lignin content it is felt that this strategy will pay greater economic dividends than the maximin approach suggested by Namkoong (1969).

Although the examples used to illustrate the technique involved wood properties only, the uniformity index procedure should also have application wherever differences in "within-family" or "within-seed source" variability are apparent. For example, one has only to walk through an open-pollinated progeny test to be aware of sometimes striking family differences in diameter variability.

JOINT SELECTION FOR HIGH MEANS AND LOW VARIANCES

In many situations, reducing the variability of performance and increasing the average performance of a quantitative character should be dual objectives of selection. One way of insuring simultaneous improvement in mean and reduction in variance is to restrict the application of the uniformity index (J) to the clones with the best average performances. The top group of clones can be determined arbitrarily (e. g., the top 10) or from a multiple comparison procedure such as Duncan's range test.

From the 10 clones having the lowest absorption coefficients, the same group of clones (8-107, 8-83, 8-134) is selected by this procedure as was selected by the unrestricted uniformity index (Table 5). This correspondence results from the clonal absorption coefficients means and variances being strongly and positively correlated ($r = 0.70^{**}$) and is not a general outcome of this selection procedure. Since the correlation between means and variances for specific gravity is weak ($r = 0.34^{*}$), a completely different set of clones (8-5, 8-24 and 8-67) is selected for uniformity from among the top 10 as was selected from among all 37 clones (8-134, 8-128 and 8-44).

A joint index of aggregate gain

An alternative method of jointly selecting for means and variances is to use an index combining measures of both variability and mean performance. If it is assumed that a unit reduction in the phenotypic standard deviation is as valuable as a unit increase (or decrease) in the mean, the aggregate gain in value of a trait j from selecting the k^{th} clone group can be expressed as

$$\Delta G_{j(k)} = \sqrt{J_o - J_k} + (|\hat{\mu}_o - \hat{\mu}_k|) \quad (\text{Equation 10})$$

where J_o is the uniformity index of the unselected array of clones; J_k is the uniformity index of the k^{th} selected group of clones; $\hat{\mu}_o$ is an estimate of the grand mean of the unselected array of clones; and $\hat{\mu}_k$ is the mean of the k^{th} selected group. Finding the group of clones giving the maximum ΔG

thus becomes the logical objective of single trait selection. Examples in Table 5 show that ΔG for absorption coefficient is maximized by selecting clones 8-107, 8-83 and 8-134--the same group selected previously. However, the group selected for specific gravity contains clones not previously selected by any other method.

Table 5.--Aggregate gains from four different methods of jointly selecting for means and variances

A. Combining low and uniform lignin content (as estimated from light absorption coefficient)

Selection method	Clones selected	μ_k	J_k	$\Delta G^{a/}$
Select only for lowest means	8-24, 8-107, 8-83	46.20	55.02	16.38
Select only for the lowest variances(J)	8-107, 8-134, 8-83	47.07	18.18	17.27
Select only for the lowest variances(J) among the top 10 clones	8-107, 8-134, 8-83	47.07	18.18	17.27
Select to maximize ΔG	8-107, 8-83, 8-134	47.07	18.18	17.27

a/ μ_k = select group mean ($\mu_o = 52.96 \text{ cm}^2/\text{g}$); J_k = select group variance ($J_o = 147.59$); ΔG = gain (cm^2/g)

B. Combining high and uniform specific gravity

Selection method	Clones selected	μ_k	J_k	$\Delta G^{b/}$
Select only for highest means	8-61, 8-49, 8-26	.401	.00438	-.0144
Select only for the lowest variances(J)	8-134, 8-128, 8-44	.351	.00021	.0225
Select only for the lowest variances(J) among the top 10 clones	8-5, 8-24, 8-67	.376	.00044	.0433
Select to maximize ΔG	1-16, 8-80, 8-26	.391	.00050	.0570

b/ μ_k = select group mean ($\mu_o = .358$); J_k = select group variance ($J_o = .00108$); ΔG = gain.

Joint multiple trait selection for means and variances

There now remains the extension of the multiple trait index concept to include selection for uniformity as well as for aggregate gain in means. The ultimate index is one which gives the maximum aggregate gain in total merit for several traits, jointly with dual selection for means and variances.

By direct amalgamation of Equations 4 and 10, the aggregate selection differential in uniformity and average performance of several traits can be found from:

$$\begin{aligned}\Delta g_k &= \sum_m \left\{ \frac{\sqrt{J_o - J_k} + (|\hat{\mu}_o - \hat{\mu}_k|)}{\frac{1}{a_j} \sigma_{P_j}} \right\} \\ &= \sum_j \left(\frac{\Delta G_{j(k)}}{\sigma_{P_j}} \right) \\ &= \sum_j \Delta g_j(k) \quad \text{(Equation 11)}\end{aligned}$$

where

Δg_k = aggregate gain in value for the k^{th} clone group, based on m traits.

J_o = the uniformity index of the unselected array of clones for the j^{th} trait.

J_k = the uniformity index of the k^{th} selected group of clones for the j^{th} trait.

μ_o = the grand mean of the unselected array of clones for the j^{th} trait.

$\hat{\mu}_k$ = the mean of the k^{th} selected group of clones for the j^{th} trait.

σ_{P_j} = the phenotypic standard deviation of the j^{th} trait.

a_j = the economic weight of the j^{th} trait.

For the combined desired characteristics of high specific gravity and low lignin content, and maximum uniformity in each of these wood properties, the clone group giving the maximum Δg was 8-5, 8-83 and 8-67 (Table 6) with a gain of 5.131 standard deviations. Another possible way of finding the group of clones which maximize the gain is to compute and rank J for the top 10 clones for Index 1. The gain, Δg , by this method is 4.8402 standard

Table 6.--Three alternative methods of selecting the group of clones giving maximum aggregate gain in average performance and uniformity of several traits

A. Combining high and uniform specific gravity with low and uniform lignin content

Selection method	Clones selected	Index 1		$\Delta G^a/$	$\Delta g^b/$
		Mean	J_k		
Select the top 3 clones using Index 1	8-24, 8-49, 8-67	6.3988	4.6551	1.0873	3.1626
Select only for the low-est variance (J) from among the top 10 clones, using Index 1.	8-5, 8-123, 8-67	5.9435	1.7829	2.8039	4.8402
Select to maximize ΔG	8-5, 8-83, 8-67	6.0290	1.9593	2.8330	5.1310

B. Combining high and uniform specific gravity with high and uniform brightness

Selection method	Clones selected	Index 2		ΔG	Δg
		Mean	J_k		
Select the top 3 clones using Index 2	8-49, 8-67, 8-24	35.8881	3.0044	0.5205	2.3454
Select only for the low-est variance (J) from among the top 10 clones, using Index 2	8-44, 8-130, 8-67	35.4248	1.2444	1.8909	4.1039
Select to maximize ΔG	8-130, 8-83, 8-67	35.5509	1.2570	2.0113	4.44907

C. Combining low and uniform specific gravity with high and uniform brightness

Selection method	Clones selected	Index 3		ΔG	Δg
		Mean	J_k		
Select the top 3 clones using Index 3	8-126, 8-27, 8-107	9.9147	1.6012	4.0266	6.5184
Select only for the low-est variance (J) from among the top 10 clones using Index 3	8-126, 8-27, 8-107	9.9147	1.6012	4.0266	6.5184
Select to maximize ΔG	8-126, 8-27, 8-107	9.9147	1.6012	4.0266	6.5194

$\frac{a}{\Delta G}$ = aggregate gain in value of Index based on Equation 10, and expressed in Index units

$\frac{b}{\Delta g}$ = aggregate selection differential based on Equation 11, and expressed in standard deviation units

deviations, which is short of maximum possible gain from Equation 11. Equation 11 is also better than ranking J for the top 10 clones based on Index 2 when high specific gravity and high brightness, and maximum uniformity, are desired (Table 6). In contrast to these two cases, selection combining low and uniform specific gravity with high and uniform brightness is equally effective by any of three methods (Table 6).

A separate program was not found necessary for finding the clone groups which maximize Δg . The best clone groups for Δg ranked fifth out of 120 for Index 1, second out of 120 for Index 2, and first out of 120 for Index 3, and it was therefore easy to detect the best groups by inspection or with the aid of some simple hand calculations.

SUMMARY AND CONCLUSIONS

Three main ideas regarding multiple trait selection have been discussed in this paper.

- (1) Maximum aggregate gain in economic value of pulpwood from selecting simultaneously for several characteristics can be accomplished using linear selection indices. In the traditional Smith-Hazel linear index, superiority in one trait can compensate for mediocrity in another. This type of index is particularly valuable in identifying the best aggregate genotypes when selection is for pairs of desired characteristics not often associated with each other--such as high specific gravity and low wood brightness, or high specific gravity and low summerwood percent.
- (2) Increased morphological and chemical uniformity. Greater uniformity in wood specific gravity, for example, might be preferable to either very high or very low genotypic values on account of the yield-quality conflicts in pulping. In selection for better wood uniformity from a group of clones, the means and variances of the numerous possible combinations of different clones, as well as the means and variances of individual clones, have to be reckoned with. Group selection rather than individual clone selection is necessary to obtain maximum aggregate improvement in phenotypic uniformity and mean value. For illustration, in the examples considered, a reduction of one standard deviation in the total phenotypic variability was considered equally valuable as a gain of one standard deviation unit in the mean. A restricted uniformity selection index is illustrated which identifies the most uniform group of clones from candidates whose means exceed some specified value.
- (3) Joint multiple trait selection for maximum aggregate gain in genotypic value and improved uniformity can be accomplished using an index procedure which gives appropriate weights to each trait for mean value and uniformity.

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APPENDIX

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C PROGRAM TO DRAW ALL POSSIBLE SUBSAMPLES OF SIZE 3 FROM
C A POPULATION, CALCULATE THE MEAN AND VARIANCE OF THE
C SUBSAMPLE, RANK AND LIST THE 100 SUBSAMPLES WITH LOWEST
C VARIANCE, RANK AND LIST THE 100 SUBSAMPLES OF GREATEST
C VARIANCE.
C
C NUM=CLONE NUMBER(1,2,3,...N),SIG=CLONE VARIANCE, AMU=
C CLONE MEAN, NC=NUMBER OF CLONES UNDER EXAMINATION.
C
C DIMENSION OF AMU,SIG,NUM EQUALS (NC).
C DIMENSION OF NUMA,NUMB,NUMC,D,G,H EQUALS (X).
C  $X=(NC*(NC-1)*(NC-2))/6$ 
C
C REQUIRED PROGRAM INFORMATION:(1)DIMENSION STATEMENT,
C (2)CARD FOR NC,(3)DATA CARDS.
C
C FORMAT OF DATA CARDS: COLS 1-2 CLONE NUMBER, COLS 3-10
C CLONE MEANS, COLS 11-20 CLONE VARIANCE. FORMAT IF FOR
C DATA WITH THREE DIGITS TO THE RIGHT OF THE DECIMAL, IE,
C 42477=42.477
C
      DIMENSION AMU(NC),SIG(NC),NUM(NC),NUMA(X),NUMB(X),
      G(X),H(X)
      NC=( )
      READ (1,10) (NUM(L),ANU(L),SIG(L),L=1,NC)
10  FORMAT (12,F8.3,F10.3)
      M=0
      II=0
      DO 100 K=1,NC
      L=K
15  L=L+1
      IF (L.GT.NC) GO TO 100
      M=L
20  CONTINUE
      M=M+1
      IF (M.GT.NC) GO TO 15
      II=II+1
      A=AMU(K)**2 + AMU(L)**2 + AMU(M)**2
      B=AMU(K) + AMU(L) + AMU(M)
      C=SIG(K) + SIG(L) + SIG(M)
      D(II)=(A-((B**2)/3))/2 + C/3
      H(II)=B/3
      G(II)=D(II)
      NUMA(II)=NUM(K)
      NUMB(II)=NUM(L)
      NUMC(II)=NUM(M)
      GO TO 20
100 CONTINUE
C THE DRAWING OF ALL DIFFERENT SUBSAMPLES OF SIZE 3 AND THE
C CALCULATION OF THE SUBSAMPLE MEAN AND VARIANCE IS COMPLETE
C AND RANKING BY VARIANCE WILL BEGIN.
      WRITE (3,800) II

```

```

800 FORMAT ('1',5X,'TOTAL COMBINATIONS OF 3 CLONES =',
16,///,T24,'RANKED',/,T24,'INDICES',T38,'CLONES',
T53,'MEAN',//)
NN=0
E=10000
DO 1 K=1,II
F=E
DO 2 JJ=1,II
IF (D(JJ)-F) 3,2,2
3 F=D(JJ)
J=JJ
2 CONTINUE
WRITE (3,101) D(J),NUMA(J),NUMB(J),NUMC(J),H(J)
101 FORMAT (10X,F20.10,5X,313,5X,F7.4)
NN=NN+1
C STATEMENT 99 DETERMINES HOW MANY OF THE RANKED VARIANCES
C WILL BE PRINTED; IN THIS CASE THE NUMBER IS 100. IF THIS
C STATEMENT IS DELETED, ALL VARIANCES WILL BE PRINTED IN
C RANKED FORM FROM SMALL TO LARGE.
99 IF (NN.EQ.100) GO TO 700
D(J)=E
1 CONTINUE
700 CONTINUE
C RANKING OF VARIANCES FROM SMALL TO LARGE IS NOW COMPLETE.
C FOR COMPARISON, VARIANCES WILL NOW BE RANKED IN REVERSE.
WRITE (3,102) NN
102 FORMAT ('1',20X,'THE',15,' WORST COMBINATIONS',//)
NN=0
E= -.999
DO 5 K=1,II
F=E
DO 12 JJ=1,II
IF (G(JJ)-F) 12,12,13
13 F=G(JJ)
J=JJ
12 CONTINUE
WRITE (3,150) G(J),NUMA(J),NUMB(J),NUMC(J),H(J)
150 FORMAT (10X,F20.10,5X,313,5X,F7.4)
NN=NN+1
IF (NN.EQ.100) GO TO 500
G(J)=E
5 CONTINUE
500 CALL EXIT
STOP
END

```


EFFECTS OF COMPOUNDS FROM CHESTNUT INNER BARK ON THE GROWTH OF
ENDOTHIA PARASITICA

Safiya N. Samman and Paul E. Barnett^{1/}

Abstract.--Fractions of the chloroform extract from inner bark of American chestnut were separated. Seven of the 25 fractions used in an assay inhibited growth of Endothia parasitica in vitro. These results provide a basis for further work toward developing a screening technique for blight resistant American chestnut selections and progenies.

American chestnut (Castanea dentata) was nearly eliminated after introduction of the fungus Endothia parasitica into this country in the late 1800's. Many attempts were made to control the blight. Interspecific hybridization with Asiatic species at one time appeared to provide a solution, but hybrids have not been successful forest trees. Radiation breeding until now has not given promising results. A selection breeding program has been under way at the University of Tennessee for about twelve years, and a total of 40 American chestnut trees have been selected to date. Last year controlled crosses in the grafted orchard yielded a good harvest of nuts and the seedlings are now being grown for a progeny test.

One hindrance in such breeding programs is the lack of an efficient test for screening progenies for blight resistance. A period of ten to fifteen years is required for each breeding cycle. Thus a method for early determination of progeny resistance is needed to accelerate the breeding program providing savings in time, labor, space, and funds.

Barnett (1967) initiated a study of chestnut inner bark, based on the observation that species of Castanea contain high concentrations of phenolics (tannins) and that infected cankers also contain a great variety of these compounds.

Barnett (1972) collected and air dried sound and infected inner bark from American chestnut trees. This material was ground in a Wiley mill and extracted in a Soxhlet apparatus. In order to partially separate some of the more polar compounds the material was extracted in sequence with petroleum ether, chloroform, diethyl ether, acetone, and methanol. Thin-layer chromatography disclosed considerable qualitative and quantitative variation in the phenolics of individual American chestnut trees. A dramatic difference was also noted between chromatographic patterns of sound and infected bark samples from the same tree. These differences were further investigated by determining the effect of the crude extracts upon the growth of the blight fungus in a potato-dextrose-agar culture medium.

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Chloroform-soluble extracts from infected American chestnut trees inhibited in vitro growth of the fungus more than any other extract. This paper presents preliminary work on the composition and activity of the chloroform-soluble extract from infected chestnut inner bark.

METHODS

Twenty grams of dry ground bark were defatted with petroleum ether and then extracted with 250 ml of chloroform in a Soxhlet apparatus overnight. The extract was reduced to dryness and taken up in 20 ml of chloroform. Five ml of the extract was fractionated with 1000 ml of 9:1 benzene:methanol followed by 1000 ml of 8:2 benzene:methanol, on a silica gel column of activity III by the "dry column" method of Loev and Goodman (1967). However, rather than cutting the column according to their method, 95 fractions, 15 ml each, were collected with an automatic fraction collector. Each fraction was evaporated to dryness under nitrogen and taken up in 4 ml chloroform. Fractions which absorbed light at 290 millimicron were assumed to contain phenolic compounds (Silvestein and Bassler, 1967).

Figure 1 is the elution chromatogram obtained from the column. Twenty-five peak fractions and eight controls of chloroform solvent were spotted within equally spaced 1.9 cm circles on Whatman #3 MM chromatographic paper. The experiment consisted of three replications distributed completely at random. After spotting, the paper was exposed to a germicidal lamp for 30 minutes, then transferred to 15 cm, sterile, petri dishes. Twenty-five ml of PDA prepared according to Barnett (1972) was poured over the paper and dishes were swirled to yield a layer approximately 1 mm deep. A 1.5 mm PDA plug containing a single germinated pycnidiospore was then transferred to each circular area.

Two assays for fungal growth were made. In the first assay a volume of each sample containing a total of 0.1 absorbance unit at 290 millimicron was used. The second assay included 50 microliters of each fraction and controls regardless of absorbance value. Colonies were cultured at room temperature and diameters measured after seventy-two hours.

The first assay was made to determine the effect of each fraction on fungal growth when the concentration of each component was 0.1 absorbance unit; thus, roughly similar concentrations of each fraction was used. Results expressed as absorbance units can be converted to concentration once absorbing materials are identified. The second assay allowed observation of retarding effects of fractions on fungal growth at the relative concentrations found in the inner bark.

Analysis of variance and a Duncan Multiple Range Test were used to test data obtained from diameter measurements of the colonies.

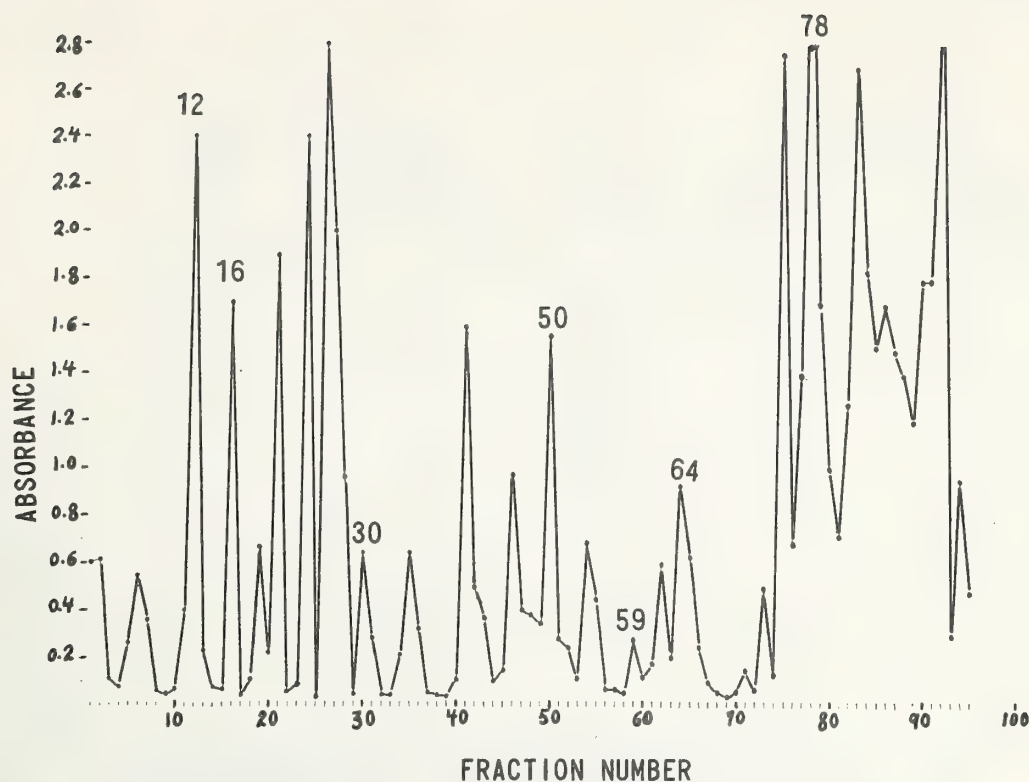


Figure 1.--Elution chromatogram of the 95 fractions collected from the silica gel column.

RESULTS AND CONCLUSION

The analysis of variance showed that some fractions significantly inhibited colony growth. Duncan's Multiple Range Tests indicated that seven of the twenty-five fractions were significantly more inhibitory to fungal growth than all the controls. The other 18 fractions had no statistically significant effect on growth and in no case did they promote growth beyond that of the controls. Mean diameter growth of colonies which were inhibited after 72 hours is presented in Table 1.

Table 1 includes the 7 fractions which inhibited fungus growth significantly in both assays; two additional fractions were more inhibitory than controls in the first assay only. This observation indicates that active fractions inhibit in vitro growth of the blight fungus similarly over a fairly wide range of concentrations; however the inhibition of fraction number 59 is greatly enhanced by a seven-fold increase in concentration. If this observation is confirmed in vivo then selection of resistant individuals would be greatly simplified.

Table 1.--Effect of some chloroform fractions on in vitro growth of Endothia parasitica.

Fract. No.	First Assay (equal absorbance)			Second Assay (all vol. 50 μ l)	
	Mean Diam. growth (mm)	% of control	Volume (μ l)	Mean Diam. growth (mm)	% of control
12	5.0	43.9	42	6.6	55.5
16	4.5	39.5	58	3.4	28.6
30	6.2	54.4	154	7.9	66.4
50	5.3	46.5	64	5.6	47.1
59	4.4	38.6	351	7.6	63.8
64	6.1	53.5	108	6.5	54.6
78	6.2	54.4	24	6.2	52.1
Mean of 7 fractions	5.4	47.4		6.3	53.4
Mean of 8 controls	11.4	100.0		11.9	100.0

The above preliminary results indicate existence of some extractible, fungus inhibiting chemicals that might be used as a screening factor in an American chestnut selection breeding program. Identification of these compounds is the next step. More research is needed to determine the fungicidal effect of components in pure form and to correlate the results with resistance in nature. Such knowledge would provide a valuable tool for selection of blight resistant American chestnut trees.

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SESSION VI

SOUTHERN FOREST TREE IMPROVEMENT
PROBLEMS AND RESEARCH PRIORITIES

R. J. DINUS, B. A. THIELGES, and O. O. WELLS

SOUTHERN FOREST TREE IMPROVEMENT PROBLEMS AND RESEARCH PRIORITIES:

A Resumé of Concern from the Twelfth Southern Forest Tree Improvement Conference

In accordance with its objectives, the Southern Forest Tree Improvement Committee is seeking an increased voice in the definition of problems, planning of research efforts, and setting of priorities by organizations responsible for forest genetics and tree improvement research in the Southern United States. Individuals organizing the Twelfth Southern Forest Tree Improvement Conference were therefore directed by the Committee to solicit suggestions from conferees concerning existing or anticipated problems and the urgency of their solution. These were to be discussed during the conference, reviewed by the Committee, and entered in the proceedings so that those responsible for planning research programs, allocating research funds, or otherwise influencing research efforts could have ready access to information about tree improvement problems as viewed by those experiencing the need.

Fifty-three of the 120 registered conferees, students excluded, responded to the problems and priorities questionnaire circulated at the conference. Though this represents only 44 percent of the potential respondents, the questionnaires showed that most tree improvement programs in the Southern United States were represented by responses from one or more of their personnel. Substantial numbers of tree improvement foresters and seed orchard managers responded, further illustrating that a cross section of concern was obtained.

Problem statements submitted by respondents were categorized into nine primary areas of concern. These are listed below along with the percentages of respondents requesting action on them and the degree of urgency attached to each.

<u>Area of concern</u>	<u>Percentage of respondents listing the area of concern</u>	<u>Mean priority ranking assigned by those listing</u>
Cone and seed insect control	64	4.6
Reproductive physiology	38	3.2
Harwood genetics and breeding	30	3.4
Advanced generation pine breeding strategies	28	4.1
Cone and seed harvesting methods	24	3.8
Fusiform rust resistance breeding	23	3.7
Pine pollen management	23	3.0
Forest gene resource conservation	15	4.0
Juvenile/mature correlations	9	4.0

The "mean priority ranking" was obtained by assigning individual problem statements on each questionnaire a numerical rating on a scale from 1 (lowest) to 5 (highest priority). These values were averaged over all questionnaires listing a particular problem to quantify the degree of urgency in that area. By these means, independent expressions of both breadth and depth of concern were achieved. For example, 23 percent of the respondents listed pollen management as a concern, whereas those requesting more information on juvenile-mature relationships were fewer, only 9 percent, but considered their need more urgent.

These measures of concern are supplemented below by discussion of the several problems underlying each area of concern. Supporting information was derived not only from the questionnaires, but also from discussions on the conference floor and from reviews by technical experts on the Committee.

Cone and seed insect control.--The most pressing concern in Southern forest tree improvement is clearly the severe, continuing reduction in cone and seed crops caused by insects. To most respondents, the effort expended on research and development in this area of concern is exceedingly disproportionate to crop value. Concern was expressed for environmental values also. Respondents repeatedly stressed that research efforts should be aimed at developing efficient, but safe controls. If balanced, integrated control systems are to be forthcoming, several lines of attack must be initiated or intensified. Listed in order of their separate priorities, these include:

- (1) Development of procedures to efficiently monitor insect impact in seed orchards;
- (2) Screening of available and new insecticides and testing of application methods;
- (3) Registration of usable insecticides; and
- (4) Establishment of biological and behavioral studies involving both pests and their predators.

Pilot tests with available insecticides could hasten development of methods for reducing losses until integrated control systems become available. The infrequency of pilot trials to date has resulted from limited funding rather than a lack of cooperative spirit. Financial restrictions also limit pilot test quality by having inhibited foundation research required for effective direction and coordination. Hence, funding of seed orchard insect research at levels commensurate with crop value is essential to alleviate the problem over both the long and short terms.

Reproductive physiology.--Individuals requesting further effort on reproductive physiology were concerned primarily with rooting improved pine and hardwood materials. Twenty-three percent of all respondents attached moderate priority to this aspect. This information was desired to facilitate research or practical activities by approximately equal numbers of respondents. Other problems within this area included reduction of losses to graft incompatibility, stimulation of early, consistent flowering and improvement of hardwood seed storage methods. Greatest urgency was given to the first of these several problems. Familiarization of plant physiologists with tree improvement problems was also stressed.

Hardwood genetics and breeding.--Interest in this area of concern was substantial, but depth of concern only moderate. This reflects the fact that numerous hardwood programs have been undertaken, but that the total effort is modest in comparison to that with pines. Half of the respondents listing this area requested more and better information on selection systems, trait evaluation, genetic parameters and genotype by environment interactions. The remainder were concerned with provenance testing or establishment and management of improved plantations. Though approximately equal numbers were interested in these latter problems, far greater urgency was attached to the need for information on establishment and management.

Advanced generation pine breeding strategies.--That pine breeders are about to begin the second cycle of selection underscores the need for research on advanced generation breeding strategies. Numerous strategies, moreover, must be developed and tested as no single strategy suits all species, areas, and organizations. This area of concern therefore drew wide attention and respondents listing it considered it second highest in priority. Major concern was expressed for intensified work on mating designs and population sizes, progeny testing methods, selection schemes, effects of relatedness, relative merits of clonal versus seedling orchards, and especially the nature and extent of genotype by environment interactions. A small proportion of the 28 percent listing this area desired new work on wide crossing, synthetic varieties, and economic consequences of advanced generation breeding.

Cone and seed harvesting methods.--This need was of moderate concern in terms of the percentage of respondents, but its solution was considered of above average urgency. Factors contributing to severity of the problem include the large size of many orchards, the short length of the harvest season, and expense or unavailability of labor in most areas. The situation clearly demands mechanized harvesting and most respondents so indicated. Increased attention by more organizations to diverse approaches is essential if development of an efficient system is to be expedited.

Fusiform rust resistance breeding.--Approximately 25 percent of the respondents listed fusiform rust as a problem and accorded it considerable urgency. Rust is not a problem in all areas and as the conference was southwide this degree of response merits serious attention. Individuals listing needs for further work on rust were from the six states with the greatest rust problem and cited as their major concerns our poor understanding of pathogenic variability, its consequences, and the relationship between artificial and field testing procedures. Also frequently mentioned was the need for additional emphasis on cooperative testing arrangements, development and release of resistant strains, and the characterization of site and environmental influences.

Pine pollen management.--This area of concern perhaps drew less attention than merited as its ultimate consequences, lower realized genetic gains, often go unrecognized. A frequent manifestation can be reduced seed yields. Concern is expected to increase as more seed orchards are established or come into production. Solution revolves around insuring control of orchard pollen quality and quantity. A contribution to these proceedings by Woessner and Franklin aptly outlines the problem and research approaches.

Forest gene resource conservation.--Considerable disparity between breadth and depth of interest occurred for this area of concern. Only 8 percent of the respondents listed it, yet they attached great urgency to action. In their view, a select tree registry clearly is needed, though most preferred a regional rather than national undertaking. In terms of preservation per se, respondents and other conferees desired cooperation with the USDA Agricultural Research Service, related Federal and State agencies, and concerned professional societies.

Juvenile-mature correlations.--This problem displayed the greatest disparity between response frequency and priority rating. Few people mentioned it but those that did thought it urgent. The concern here is with time. The ability to select accurately at early ages means short generation intervals, and therefore greater genetic gain per unit time. To define the optimum age at which to take and use measurements, the juvenile-mature correlations for each important trait in each species must be determined.

Mention of these areas of concern underlines their importance as obstacles to full realization of returns from Southern tree improvement programs. Though no doubt incomplete, this listing does provide a beginning. In this regard, most respondents further expressed the desire for more cooperation and, especially, coordination in research planning. A need also exists for more active synthesis of diverse results as well as increased willingness and means to apply research findings.

Conference Chairmen

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